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RELATIVITY AND ETHER DRIFT.

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One who rides in a train on a rainy day notices that the streaks formed by the raindrops on the windows are not vertical, but run diagonally across the glass. The angle which they make with a vertical line depends upon the speed with which the raindrops fall and the speed of the train. In like manner

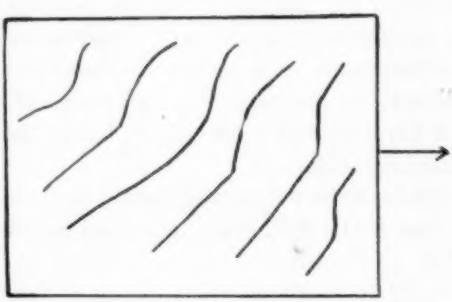

Fig. 1.

Falling raindrops.

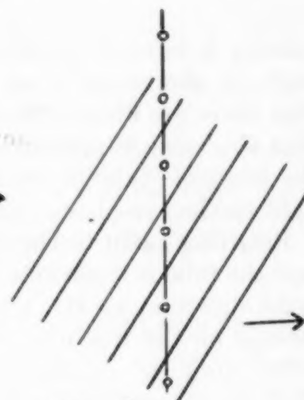

Fig. 2.

Carry a hollow tube in the rain.

if one were attempting to carry a hollow tube in a rain storm and protect the inside from getting wet he would slant it at an angle depending upon the speed of the falling drops and his own speed.

In 1727 Reverend James Bradley discovered that the light

from a distant star does not strike the center of the eyepiece, but is shifted slightly as illustrated in the figure.

The shift or aberration angle ϕ is in this case due to a combination of two velocities, one of the earth in its orbit which is 19 miles per second, and the other the velocity of light which is approximately 186,300 miles per second. Since the latter

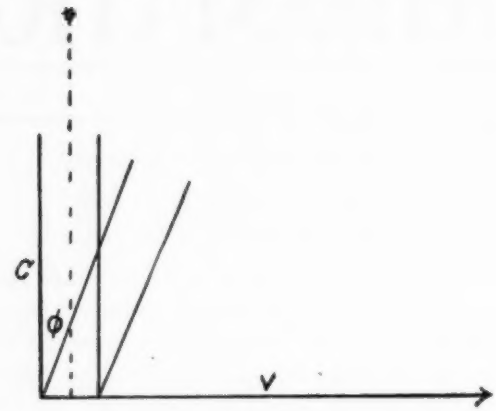

Fig. 3.

number is so much greater than the former it follows that the angle of aberration is an exceedingly small one. Assuming that there are about 206,000 seconds in a radian it comes out that the value is approximately 20 seconds. In the figure (3) the telescope tube is tilted through the angle ϕ to bring the light to the eye-piece. Compare Fig. 2.

Referring again to the illustrations connected with the train and the tube it is obvious that if the rain storm traveled in the same direction as the train and with the same velocity the streaks on the windows would be vertical. The same is true with reference to the tube. Bradley concluded, therefore, that since there was a measurable aberration it must follow that the medium through which light travels and to which we have given the name ether cannot travel with the earth, but must remain stationary with reference to it. This theory of a stationary ether was held by all scientists until 1886 when Professors Michelson and Morley performed an experiment which has perhaps been more generally discussed than any other physical investigation. Having constructed an instrument by which linear measurements could be made directly

in wave lengths of light, and which could be read easily to the fortieth of a wave-length, Professor Michelson in collaboration with Professor Morley undertook to determine whether or not there existed an ether drift as the earth passed through it.

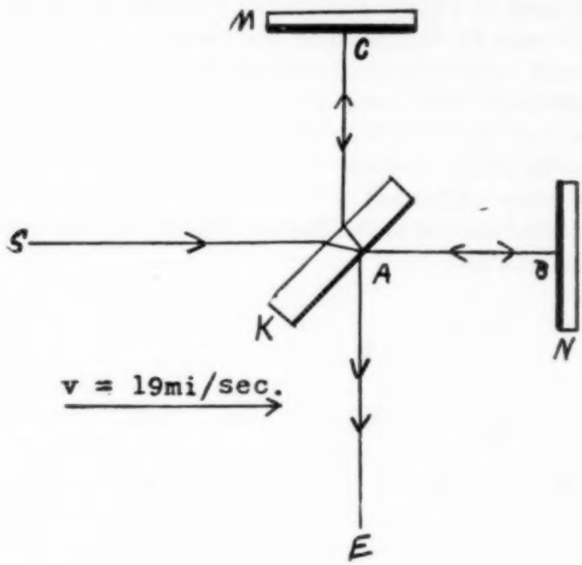

Fig. 4.

MIRROR K IS HALF-SILVERED, SO THAT THE LIGHT IS IN PART REFLECTED AT A AND A PART GOES THROUGH THE SILVER FILM TO B. IN PRACTICE A GLASS COMPENSATOR OF THE EXACT SIZE OF K IS PLACED BETWEEN K AND N TO AFFECT THE DOUBLE JOURNEY THE LIGHT MAKES THROUGH K.

Fig. 4 will explain the method of investigation. The light is supposed to divide at A and travel straight ahead to B, and at right angles to C. Mirrors M and N are arranged to throw the beams of light directly back upon their courses. If these beams are equal or differ from each other by a whole number of wave lengths they will come to the eye at E with constructive interference. Let us assume this to be the case and then imagine that while the light is traveling from A to B the mirror M is moving forward with the earth's motion. If the ether is stationary as the aberration theory seems to indicate, there would be a shifting of the fringes as observed by the eye at E.

The amount of shift according to the theory should be four-tenths of a fringe width. As a matter of fact no displacement was observed, although the instrument was sufficiently delicate to detect one-fortieth of a fringe width. This experiment, giving antagonistic results to the experiment of Bradley, has been a source of puzzlement to the scientific world for many years. It may be compared to the doctrine of predestination and free-will in theology, or, sticking to the domain of physics, to an irresistible force meeting an immovable body. Various attempts have been made to reconcile the results of these two experiments, for an account of which the reader is referred to standard works on Optics.

In the development of the theory of relativity three formulae are in common use:

$$\text{I.}\quad L = L_o\sqrt{1-\frac{v^2}{c^2}}$$

$$\text{II.}\quad M = \frac{M_o}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$\text{III.}\quad T = \frac{T_o}{\sqrt{1-\frac{v^2}{c^2}}}$$

L_o, M_o, T_o represent the length, mass, and time of a body at rest. This condition is never fulfilled. L, M, T represent the length, mass and time of a body moving with velocity V.

These are very interesting formulae as will appear from a brief study. It is obvious that the apparent length of a body depends on its velocity with reference to the velocity of light. If we take the velocity of a rifle ball as one mile a second, which is a little larger than is actually obtained, we find that the length of the ball is decreased as follows:

$$L = L_o\sqrt{1-\left(\frac{1}{186000}\right)^2} = L_o\sqrt{1-\frac{1}{35x10^9}}$$

The expression under the radical represents the shortening of the bullet and is exceedingly minute.

If we consider the velocity of the earth in its orbit, which is 19 miles a second, we find the shortening of the earth by a similar process.

$$L = L_0\sqrt{1-\left(\frac{19}{186000}\right)^2} = L_0\sqrt{1-\frac{1}{10^8}}$$

Expressing L_0 in inches we have

$$L = 8000 \times 63360 \sqrt{1 - \frac{1}{10^8}} = 5 \times 10^8 - 2.5,$$ or the earth

s shortened 2.5 inches. It will be observed that approximate methods have been used in these calculations.

If we substitute for V velocities which are more nearly equal to the velocity of light we find that the length materially decreases and falls to zero when the body moves with the velocity of light. This is one of the reasons which lead physicists to believe that the velocity of light is the limiting velocity which may never be surpassed or equaled by a material object. In passing it may be noted that the second formula shows us that the mass increases with the velocity, a conclusion which has been sufficiently well verified. It follows, therefore, that a rod moving parallel to itself with the velocity of light would become a disk of zero thickness and infinite mass. The results afforded by formula III are rather more philosophical than physical. It is hard to give a physical meaning to the situation where time becomes infinite; but when we deal with infinity either of time or of space we soon pass beyond the limits of human understanding. The bearing which formula I has on the ether drift theory is obvious.

In Fig. 4 the entire apparatus is moving with the earth in the direction of the arrow. This means that the parts supporting mirror N are shortened as shown by the formula. If this is the case the failure to detect a displacement of the fringes may be fully accounted for. In the formulae and all postulates made by Einstein the existence or non-existence of the ether plays no part.

The happy solution of this perplexing problem was seriously disturbed by the researches of Dr. D. C. Miller, of the Case School of Applied Science, who carried on his investigations at considerable altitude and discovered a certain shifting of the fringes. In collaboration with Professor Morley he had previously performed this experiment at a lower altitude, and their results checked with the original work. The problem has now become of world-wide interest. Quite recently Dr. Roy J. Kennedy, of the California Institute of Technology,

repeated the investigation with an improved form of apparatus, and he finds no sign of a fringe shift due to the earth's motion. Repeating the experiment at considerable altitude a similar conclusion was reached. Professors Piccard and Stahel, of the University of Brussels, have repeated the experiment by use of a balloon in which the apparatus was placed. The entire balloon was rotated and the results were recorded photographically. A slight shifting of the fringes was obtained, but this might easily have been due to unexpected and uncontrolled temperature changes. This experiment tends to show that if any ether drift exists it does not increase with the altitude. This is in conformity with the theory of relativity.

Another interesting experiment bearing on this problem has been suggested by Professor Silverstein and carried out by Professors Michelson and Gale.

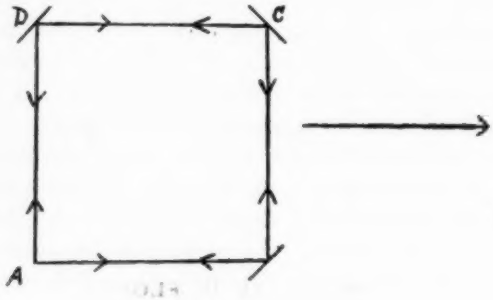

Fig. 5.

Light from A is sent to B in the direction of the earth's motion and to D at right-angles to it. By means of 45 degree mirrors placed inside of iron pipes the rays of light traveled several times around the rectangle in each direction and came together again at A. The distances being identical in each direction constructive interference might be expected. Since, however, the velocity of the earth along DC is less than that along AB the pipe AB would experience a greater decrease in length than the pipe DC. Knowing the distance AD and assuming the spherical shape of the earth it is not a difficult problem to compute the two velocities in question, and from this to figure the relative shortenings of the pipes. The results obtained check the Einstein theory with a closeness which is quite remarkable. Indeed, it seems to many physicists that this is the real *experimentum crucis*.

One who reads the story of these remarkable investigations originated by Bradley and carried on under such difficult conditions by Michelson, Miller, and others must be strongly impressed by two considerations. In the first place it is difficult to conceive of a series of investigations which would have less practical value than those which have been described. In no part of the work is the earning of a dollar concerned. Whether the ether moves with the earth or remains stationary is, so far as we can at present observe, of no practical or monetary value. That the work has been appreciated by the physicists of the world is evidenced by the award of the Nobel prize to Professor Michelson and the American Association prize to Professor Miller.

In the second place it is well worthy of note that while antagonistic results seem to have appeared again and again in these researches, no one has attempted to put his personal reputation above the open-minded searching for truth. A few centuries ago physicists were accustomed to manifest bitterness when their opponents undertook to find flaws in their investigations. Fortunately that spirit has entirely passed. May we not hope in a few more centuries that those whose researches lie in the field of theological inquiry shall have reached a similar intellectual attitude?

TUNG OIL IN FLORIDA.

That American tung oil, an urgent need of the national paint and varnish industry, will begin coming into the market before 1928 is the belief expressed by Henry A. Gardner of the Institute of Paint and Varnish Research in a report to the American Chemical Society.

The project of developing an American tung oil industry was undertaken by the American paint and varnish industry some three years ago. Three hundred acres of land in the vicinity of Gainesville, Florida, were planted with tung trees to demonstrate to Florida farmers the possibilities of such a crop. Nurseries were established for distribution to other planters, and it was not long before one organization acquired a large amount of land near Gainesville and planted 1,200 acres of it in tung trees with seedlings from the nurseries. In this vicinity there are now about 300,000 tung trees, from one to two years old, some of which are bearing a substantial crop of seeds. The oil yield may range from 400 to 1,800 pounds per acre, Mr. Gardner says, beginning from the third to the ninth year. The average producing age of the trees has been estimated at from 25 to 30 years.

From these nurseries and from others established by the Florida Experiment Station, seedlings have been supplied to individuals in Alabama, Cuba, Florida, Georgia, Louisiana, Mississippi, South Carolina, Texas, the Philippine Islands, and Hawaii.—*Science News-Letter*.

THE PLACE OF THE FUNCTION CONCEPT IN SECONDARY SCHOOL MATHEMATICS.

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A French wit once remarked that words had been invented for the purpose of hiding ideas. While we would certainly not go as far as that, we may perhaps agree that words frequently come dangerously near to confusing ideas. And it is a very unfortunate circumstance if one and the same word is used to represent different ideas; for in such a case we have no remedy but to use more words in an attempt to clarify the ideas which seem to be confused initially. Paraphrasing the well known saying concerning the remedy for the evils of democracy, we are forced to the position that the only escape from the entanglements into which words have led us can come through the use of more words. And so it happens that we come together in an attempt to remedy through the use of words the evils to which such use has led us.

The word function is one of those which is used with considerable variation in meaning. I don't know what the Century Dictionary gives as its principal meaning; but to the ordinary non-scientific person it doubtless means a party of a certain solemnity and diginity. Again, for the non-mathematical scientist, to the biologist and the physiologist, it means purpose, value or usefulness. With these meanings of the term we shall not be concerned. And I believe that I am not judging wrongly when I think that to all of my hearers the word function as used in Mathematics has a quite definite meaning. But, if I am not going to add to the confusion of words, I had best dwell for a little upon what the content of the mathematical concept function may be conceived to be, so that we may become aware of its scope and of its significance for the modern world.

Let us remember, first of all, some aspects of its history. For the analysts of the 18th and early 19th century, a function of one or more variables was an expression involving these variables which could be written down by means of recognized mathematical operations; so, e. g., $\frac{a+1}{a^2-3}$, Arc sin $\frac{a+4}{3}$, log $(a+26)$ were functions of a. It is a fascinating chapter of the history of Mathematics which treats of the way in which this primitive concept was forced to take on ever wider scope,

until finally Dirichlet, about 1825, said that y was a function of x whenever to every value of x between two fixed limits a and b there corresponds a value of y according to a definite law. The idea of a formula by means of which y was expressed in terms of x is here replaced by that of "correspondence according to a definite law"; this remains, of course, rather vague until we specify what is meant by a "definite law" and what we mean by "every value of x." There is no doubt that Dirichlet meant x to be a real number between the real numbers a and b; but the important element in his definition is the idea of *correspondence between the values of x and of y;* it has been carried into an even more central position in later extensions of the function concept, made necessary by the extension of the domain of analysis. It is this idea, moreover, which gives the function concept its wide sweep of generality extending far beyond the field traditionally held to be that of Mathematics and which places it in the forefront of the mathematical concepts which it is of significance for every person of liberal education to be familiar with. Speaking in the most general terms, we say that if P and Q are any two well defined assemblages or classes of mathematical entities of any kind whatever, then a correspondance of any kind whatever which associates an element of Q with every element of P is a "function on P to Q." If P is the set of real numbers from —1 to 1, and Q the set of positive real numbers, then the formula $\sqrt{1-p^2}$ establishes such a correspondence—it is a function on the class of real numbers from -1 to $+1$, to the class of positive real numbers. If P consists of all spheres with center at the top of the Washington Monument and Q the set of positive real numbers, then a correspondence can be established by associating with each of the spheres of the class P the lateral area of the cone whose vertex is at the top of the Juneau Monument in Milwaukee and which envelops that sphere, measured in square miles. Or, if the class P consists of all closed wires surrounding a circle of radius equal to 2 feet and with center at A, and Q is the class of real numbers, then a correspondence is set up by the potential at A of an electric current of given intensity flowing through the closed wire. Again, if P is the class of positive real numbers from 0 to 400 and Q is the class of real numbers, then a functional correspondence is established when to every element p of P we cause to correspond that element q of Q which measures in

seconds the time necessary to completely dissolve a pound of pure salt in 10 gallons of distilled water at the temperature whose centigrade reading is given by p. The reader will readily supply further examples to illustrate the broad significance of this concept.

He will then notice that the elements of the classes P and Q are entities of considerable variety, and that functional relations pervade a large part of human experience.

Let us carry our thought still a little further, even though this may lead us beyond what is at present required by mathematicians. In the Gifford lectures for 1921 and 1922, E. W. Hobson characterized a functional relation as a causal connection in which both cause and effect are measurable, i. e., correlated with real numbers. It is indeed not difficult to see the close intimacy which exists between functionality and causality and it would be extremely valuable for the appreciation of the value of Mathematics to clarify the ways in which these important concepts hang together. But enough has been said, I hope, to indicate a direction of thought. And if we agree that the understanding of causal relationships is one of the outstanding purposes of all education; that to gain insight into the causal connections operating in the world in which we live, into the physical forces, the spiritual forces, the economic forces, the vital forces which carry forward human existence and establish the framework within which our lives have to be lived, is the ultimate aim of all intelligence, then we will perhaps accept the conclusion that the functional concept should occupy a position of fundamental importance among the ideas with which schools and colleges make the minds of young people familiar. If we recognize, furthermore, the remarkable opportunity which the teacher of Mathematics has to introduce his students to some of the important aspects of this concept, we will understand why the value of Mathematics as a subject of study in the schools and colleges depends, apart from the important technical training which it furnishes, upon the measure in which it contributes to the understanding and the appreciation of the function concept.

But I fear that I have been carrying coals to Newcastle. For I doubt not that all of you are fully aware of the importance of the position I have been urging. And what you expect of me is to give you some indication of how this end which we all recognize as desirable, is to be accomplished in the high schools. And what I shall try to do to meet these expectations may be summarized

in two theses: Secondary School Mathematics furnishes opportunities for laying the foundations for a genuine understanding of the function concept; and, the function concept can be made to enrich and clarify much of the content of the traditional high school courses in Mathematics.

But two statements are necessary before I come to this more useful part of my remarks. The first of these is to furnish a transition from the rather abstract things I have been saying to our main object. We have recognized as the essential feature in the function concept the idea of "Correspondence between arbitrary elements of two classes of entities." Now the concept "arbitrary element of a class of entities" is usually called by the technical name "variable"; the class to which the element belongs is called the "range of the variable." What we have called a function on P to Q is ordinarily spoken of as a functional relation between an independent variable whose range is the class P and a dependent variable whose range is Q. The reader may be interested in restating for himself the various examples of "function" which were given above in this familiar form; and also to translate familiar examples of functional dependence into the more general form which I have used.

The second remark is intended to relieve any anxiety that may be felt lest I should urge you to introduce the function *terminology* with all its abstractness into the class room. Both the concept number and the concept function in the students' experience with them pass through numerous stages before they emerge in their true generality. From the notion of positive integer, we pass through successive extensions to the integers, the rational numbers, the real numbers, the complex numbers, the algebraic numbers, the elements of a general range. So from the notion power of a single variable x, we pass through successive stages to polynomial in x, to rational function of x, to trigonometric functions and exponential function of x, to functions of two or more variables and so on through a vast development. Now for the larger part of the secondary school work, "function" can very well be restricted to mean rational function of one or two variables. And, furthermore, I can say that most probably the place of the function concept in the secondary schools even if thus restricted is chiefly in the air, in the atmosphere, in the minds of the teachers. It is the point of view from which a subject is taught that is of importance, the direction in which it sets the pupils thinking that matters chiefly.

And now let us try to come to somewhat closer quarters with our subject. What opportunities are furnished by the mathematics of the high school to lead the student to an understanding of the function concept, and how can this concept enrich the content of high school Mathematics. Let us assume, for convenience, that the high school course consists of a year of Algebra followed by a year of Plane Geometry. Since this is perhaps the most common, although by no means the only possible arrangement, and since, once we succeed in pervading the work of the first two years with the function concept, it will not be difficult to develop it further in later work in Mathematics, I shall confine my attention to the elementary courses of the freshman and sophomore years.

1. At the time the high school freshman begins the study of Algebra, he has become acquainted with the system of positive rational numbers and with the elementary operations upon them. His first step into the broader realm of Algebra consists most frequently in learning the use of literal numbers, to which he is usually introduced by means of the statement "letters are used to denote numbers." Now this is manifestly vague, for the question arises as to what sort of numbers the letters are used to denote. The answer clearly is that at first they denote positive rational numbers, that a little later they denote rational numbers, negative as well as positive, still later they come to stand for real numbers, and finally, perhaps, for complex numbers. Now the important thing I would have recognized is that a letter is a *variable* whose range is first the class of positive rational numbers, extended later on successively to the class of rational numbers, the class of real numbers and the class of complex numbers. Without introducing the abstract concept of variable, we can reach our aim in the schools by insisting on the fact that a letter a stands for an *arbitrary element* chosen from a definite set of numbers. And this can be accomplished in a very simple way. Early exercises on adding of like terms, on removal of parentheses, on special products can be used for this purpose. If we have found that $5a+3b-2a+4b = 3a+7b$, we can bring out the fact that letters denote arbitrary elements of the class of positive rationals by having the members of the class substitute rational numbers for the letters and verify that numerical identities can thus be obtained. This gets greater significance when we come to such formulae as $(a+b)^2 = a^2+2ab+b^2$ or $(a+b)(a-b) = a^2-b^2$. When students see that they can be put to use for carry-

ing out numerical calculations, e. g., $81^2 = 6400+160+1$, or $98 \times 102 = 10{,}000-4 = 9{,}996$, they begin to appreciate these relations not as mere tricks but as valuable aids in numerical work, they become aware of the wide sweep of Algebra, of the significance of a variable. It enriches the content of this elementary work. When later on negative numbers have been introduced, and when irrational numbers have come in, it is important to constantly illustrate the fact that the letters now denote arbitrary elements of a larger class of numbers, by making numerical substitutions for the letters in the formulae with which the student becomes acquainted. A reduction like the following:

$$\frac{a}{a+b}+\frac{b}{a-b}=\frac{a^2+b^2}{a^2-b^2}$$

and others of such character, so frequently a stumbling block for students, often appear in a different light when they are shown to be *general* statements, special cases of which, such as the form,

$$\frac{8}{13}+\frac{5}{3}=\frac{64+25}{64-25}=\frac{89}{39}$$

can be written down by every member of the class. Without going into further details, I would enunciate the following principle:

Enrich the significance of work in elementary algebra by making arbitrary substitutions of numbers for letters in the formulas, emphasizing at each stage that the numbers may be selected from one or another definite class.

2. A new element is introduced when we come to the solution of equations.

A teacher who is imbued with the function idea might proceed as follows: Suppose we have to solve the simple equation

$$\frac{2a-3}{4}+\frac{a}{2}=7.$$

The left side is an expression which represents a number; the particular number it represents depends upon the number which a represents. We begin by substituting for a a variety of numbers; if $a = 4$, the expression represents $5/4+2 = 13/4$; if $a = 6$, the expression represents $9/4+3 = 21/4$; if $a = 8$, it represents $13/4+4 = 29/4$, etc. The problem is now to find what number must be taken for a in order that the dependent expression be

equal to 7. We develop in this manner the point of view that this equation stands for a problem in which a question is asked, viz., what number to choose for the independent letter a, in order that the dependent expression $(2a-3)/4+a/2$ shall be equal to 7. This question is transformed by gradual steps into equivalent questions, until we reach one which can be answered immediately.

The question implied by any equation in a single unknown can always be put in the following form: For what value of a variable, x, whose range is given, will this or that function of x take this or that value. While it is probably advisable to postpone the explicit presentation of this view until the students have become more mature, there is no reason why the teacher who understands it, should not utilize the advantages which it presents, particularly since in this way the student is prepared for the emergence later on of the function idea. For this point of view has at least two immediate advantages: 1) It suggests in a natural way the successive enlargements of the number system. For example, the question implied by the equation $a+7 = 10$ is answered readily; the question $a+10 = 7$ is not answered readily by a student who has not yet become familiar with negative numbers. It leads to the question whether we can enlarge the range of the variable so as to enable us to answer this new question. 2) It removes a difficulty frequently encountered in the solution of quadratic equations by factoring; how can the equation $x^2-5x+6 = 0$ give for the unknown both 2 and 3; does not x have to be one or the other? This type of question has perhaps not yet entirely disappeared from the classroom. It is less likely to appear when the problem is put as follows: What number of the range of intergral numbers will, if substituted for x, give to x^2-5x+6 the value 0? Our second point may be stated as follows: *Think of an equation as a problem in which we are asked to choose for a variable a number from an agreed class of numbers in such a way that a given function of this variable shall be equal to a given number.*

3. It is an experience of many years of teaching which has led me to the belief that the large number of mistakes made in elementary algebra arise from a failure to recognize the importance of the order in which two or more operations are performed. It is not difficult to see that the student who replaces $(a+5)/(a+6)$ by $1+5/6$; or, $\sqrt{a^2+9}$ by $a+3$; or $(a+3)^2$ by a^2+9 is simply

interchanging the order in which certain operations are to be performed. Now human experience from its simplest forms, such as putting on our clothes, to the most complex ones such as the settling of international disputes, is full of examples, in some of which (such as putting on coat and putting on hat) the final result is the same no matter in which order two or more operations are performed; while in others (such as putting on shoes and putting on stockings or such as deciding upon a course of action and thinking the matter over) the order is of very great importance. Errors of this sort referred to should then be much less frequent if $(a+5)/(a+6)$ were thought of not as an "expression" but as the result of performing various operations upon the variable a, i. e., as a "function of a." For then the whole width of human experience would lead to a careful consideration of the importance of the order in which these operations are performed, and the person who has been trained carefully to consider whether the order in which operations are performed does or does not make a difference, should be better capable than others of judging the value of certain popular forms of arguments. This leads us to the following conclusion:

Bear in mind the functional character of "algebraic expressions"; they are obtained by means of the operations of algebra and they depend many times on the order in which these operations are performed.

4. Let us end by considering briefly the high school geometry in the light of the point of view developed in the preceding pages. We observe in the first place that the various "formulas" of geometry furnish useful material for illustrating the function concept. But, apart from this fact which has been quite widely made use of, I want to point out that geometry is capable of contributing in a much richer way to the development of the function idea. For it is here that the student can get probably for the first and perhaps for the only time in his high school career, an object lesson in the development of science. A particular example will make clear what I have in mind. When it is found that the area of a triangle depends upon its base and its altitude, we have an example of one variable, viz., the area of the triangle, depending on two other variables, viz., the base and the altitude of the triangle; that is, the area of the triangle is a function of its base and altitude. The next step in the study of the area consists in determining *what* this function is, i. e., in finding out in what manner the area depends upon the base

and the altitude. And once this exact relation has been determined, it becomes the basis of further deductions from which important consequences can be derived. Now this procedure reveals the main features of the development of scientific work, viz.: finding out what the variables in a given domain are and which of them are related to each other, determining the precise nature of these relations, exploring their consequences. The teacher, who has once understood this idea, will find numerous illustrations of the same sort throughout the work in plane geometry. It is interesting to observe that in the geometry of the high school curriculum this scientific process is sometimes left incomplete, thus illustrating the familiar fact that scientific advance in a given field is frequently held up. When it has been shown, for instance, that in a triangle with two unequal sides the angles opposite them are unequal in the same order, we have learned that there is a relation of such sort between the sides a, b and the opposite angles A, B that when $a/b>1$, then A/B will also be greater than 1, and here the matter is left until in trigonometry the student reaches the Law of Sines. Would not the teacher who is familiar with the function concept and who is aware of its far-reaching importance seize the opportunity furnished by this and similar examples to enlarge the student's horizon, to bring his mathematical thinking in direct and useful contact with other aspects of his life and to prepare him for a profounder understanding of the nature of scientific problems?

EXPERIMENTAL COLLEGE.

An experimental college, with 250 volunteer students, is to be conducted at the University of Wisconsin in order to find improved methods of teaching freshmen and sophomores.

During the first year the experiment will be limited to 125 freshmen, and in the second year freshmen and sophomores will both be studied.

Announcing the plan, Dr. Glenn Frank, president of the university, states that the experiment will enable the university to "test out forms of curriculum and methods of teaching so radically different from the prevailing curriculum and method that no university would feel justified in adopting them for its entire student body in advance of satisfactory tests under controlled experimental conditions."

President Frank states that the quality of the teaching staff of the experimental college will be such that, whatever method be tried out, the students will not lose by not taking the regular courses. The students will receive the same credit for their two years of experimental education, as if they had enrolled in the main branches of the university.—*Science News-Letter.*

HOW TO TELL STUDENTS HOW TO STUDY CHEMISTRY.

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We are entering into a widely discussed and a very difficult subject when we undertake anything regarding the methods of studying branches of knowledge of any kind. The methods of attacking the study of chemistry are not so widely discussed but they are difficult to get at in any scientific way. Not all that has been determined and discussed regarding the teaching of chemistry could be related to the study of the subject. Many teaching principles may be applied, however, if tables are turned the proper way. The most important thing that can be said in this regard is that the methods that can be applied to studying will have to be gone into deeper and with the consumption of more time in the process of studying than in the process of teaching. In the many articles published by leaders in the field regarding laboratory instruction in the last few years, none contain anything that would help the student study a lesson in the text excepting some remarks to the effect that scientific thinking is more important than committing facts to memory. This same general proposition constitutes the kernel of nearly every magazine article or lecture published within the past three years regarding the teaching of text book material.

Then of course the teacher's task is to convey to the student an idea as to how he can do scientific thinking on his subject. But the definite task will be found to be, to tell the student how to think for each special phase of the work as it comes and perhaps on each topic in its order. Some helps along the line in general may be found in the discussion of the psychology of chemistry teaching.[1]

This is a general discussion for the teacher. The intention of this article is to show by some illustrations how the general principles may be applied by the student in studying different phases of the work in chemistry. First, how may it be applied in studying definitions. The teacher can put it up to the student as follows: Your problem is to frame this definition. You will find the parts all in this mass of material, which is the topic in the text. First you must select and trim down the parts that are necessary. Then you must put them together

[1] A. E. Brown and W. G. Bowers, School Science and Mathematics, Volume 23, No. 8.

so that they will fit into each other and produce a structure that can be distinguished from others of its kind. The proposition might also be put this way: Here is an accumulation of trees, rocks, etc., on a landscape. Your problem is to select those that are characteristic to the part you want to describe. That is, those that belong on that part and no other. Include these in your survey so that the owner will not get over on the other territory.

Then the student wants to know how to study principles and laws. He can be told in the first place that a law is just a part of a principle. He can be reminded that all that is said in the text about matter and energy pertains to the principle which is, that because of energy different kinds of matter exert some sort of action toward each other, and that in studying that action someone arrived at the law, that matter is not created or destroyed in chemical reaction. Tell the student to see if he can find out how the discoverer arrived at his discovery. This will give him a problem of selecting and organizing concentrated statements from a lengthy discussion embodying several topics.

Theories and hypotheses may also develop from some general principle or principles. The general and fundamental facts may be organized in such a way that an accumulation of causes and effects calls for a certain conclusion. If the author of the text calls this a theory, the student may be reminded that his part of the work is to assemble the evidences that bear on the case and determine why it is not sufficient to call the conclusion a law. The conclusion may be constituted of several parts. The student may be asked also to determine if the parts are related closely enough to call them attributes to one theory. If the author calls the conclusion an hypothesis, the student may be asked to assemble the evidences which pertain to the case and determine whether or not the conclusion is the only one that can be drawn, or if it is a satisfactory one in the light of the evidence. If more evidence is thought necessary to justify the conclusion, he may know why it is called an hypothesis instead of a theory. This does not necessarily mean that the student must make hypotheses and theories of his own, but it means that he has the problem of relating the facts to the conclusion, determining the strength of the evidence bearing on the case, recognizing the reasons for the conclusions being termed hypotheses, theories or laws, and noting the

relation of the conclusions whatever they may be to the science of chemistry. The student should not be discouraged if he has to read everything given in the text on the proposition twice over before he is able to begin this sort of analysis. He should be advised to read the text once all of the way through before he begins to underscore pertinent facts. This may be done on the second reading. Then, if the analysis cannot be made to his own satisfaction, he should read the third time. He may find something that he overlooked, not knowing that it was important until he saw the need of it in his analysis or synthesis as the case might be. Students invariably complain about the amount of time necessary to do this sort of thing, and of course if we expect this sort of work, we must avoid too large assignments. Students will say, "If the teacher would only do the underscoring for us, we could do twice as much." They mean that they could get the kernel easier if the teacher cracked the nut and picked it out of the shell for them. The teacher never should do that until he sees that the student is absolutely unable to do it himself. He will generally have enough to do to get the remnants out of the deeper recesses of the shell. The teacher does well to tell the students that they cannot take chemistry by storm, and that all will have to work patiently at first.

Telling the student how to study reactions would be almost like telling the teacher how to teach them excepting in this case the student must of necessity be one or two steps behind the teacher. There are many different kinds of problems in this field and everyone encountered has more difficulties than the preceding one. The student will apply what he has learned about the last one only to find that there is some recess which he did not penetrate and he will have to leave that for the teacher at the next recitation hour. About the best thing to say to a student who wants a rule by which he can work out his equations, is that this sort of work is like arithmetic or algebra, one rule or even five rules will not apply, but he will patiently get that little by little throughout the year and all of the years in the future which are devoted to chemistry.

Students do not have much trouble with the mathematical problems involved in elementary chemistry. The teacher has one chief thing to tell them when he undertakes to tell them how to study that phase of the work, that is, that the mathematics of chemistry must be tackled by the same methods,

rules, and formulae as are used in the solution of other mathematical problems. The teacher can say to the student that nine-tenths of the problems connected with elementary chemistry involve the rules of ratio and proportion and that he should review that phase of his arithmetic if he wants to get along well. There is one formula that the teacher needs to emphasize over and over, that is, atomic or molecular weight of one reagent is to atomic or molecular weight of the other reagent as the real weight of the one reagent is to the real weight of the other reagent. It should be shortened to this form: at. or m. wt.: at. or m. wt. = r. wt.: r. wt. Then the teacher will need to tell the students scores of times to avoid, when he writes the chemical equation to find the numbers to substitute, putting all four of the numbers going with a double decomposition equation in the four places in the above mathematical equation, but to put the molecular weights of the two involved in ratio with the real weights of the same two. Concerning all other mathematics the student should be told to get it little by little as it comes.

Studying properties of elements and compounds is the one phase out of five that cannot be made much like a problem which requires thinking instead of memory work. When the student asks for a method of studying properties and uses, about the best thing that the teacher can do is to say that sheer memory has to be called upon to a great extent in this phase of the work. However, schemes and systems can be applied which will make the study of chemical and even physical properties so closely related to scientific thinking that the memory work is not difficult. It seems to develop into a type of its own which becomes almost second nature to the chemist. In the first place, properties and uses are so closely related that in most cases if one knows the use he knows the property and if he knows the properties he has a good idea as to the uses. In many cases, one or the other is familiar to begin with.

Properties of elements in the same group can be compared and those of elements in different groups can be contrasted. In fact, properties and uses can be related, organized and tabulated until there is a science there as much as there is in zoology or botany, according to the old definition of science, which says that science is classified knowledge. However, it is not the classification after it is made that helps the student so much to obtain a knowledge of the subject, but it is the

student's efforts to organize and tabulate the facts in such a manner that he sees clearly the contrasts and comparisons which are responsible for the different classes. This sort of work furnishes a problem even of such things as properties and uses.

To sum this whole matter up, every phase of the study of chemistry should be made into a problem which calls for scientific thinking on the part of the student.

AN APPARATUS FOR STUDYING CENTRIFUGAL FORCE.

By Loyd E. Hunt,

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In a recent number of School Science and Mathematics, April, 1926, (XXVI-4-423) Klopsteg has called attention to a defect in the type of apparatus usually used in college physics laboratories for the experiment on centrifugal force. This defect, long recognized by most instructors, lies in the fact that the equilibrium between the centrifugal force and the restoring force which opposes it is inherently unstable. In the same article Klopsteg describes a new form of apparatus in which this difficulty is overcome by making the centrifugal force stretch a spring instead of causing it to lift a weight. This will undoubtedly remove some difficulties of manipulation and the experimental results quoted show a very high degree of agreement between the measured and computed values of the force with which the spring is stretched.

From the teaching standpoint there is another, and as it seems to the writer, a more serious defect which the new apparatus shares with the old. The nature of this defect may be indicated by saying that both the forms of apparatus under consideration are designed primarily as devices for *measuring* the centrifugal force rather than as means for *studying the way in which the centrifugal force varies* with change in any one of the three factors upon which it depends. The latter purpose requires an apparatus sufficiently flexible so that the student may readily keep any two of the three independent variables (mass, radius, and speed of rotation) constant and determine by a series of measurements the way in which the centrifugal force depends upon the third. Three such simple experiments in each of which a different independent variable is used would then serve to give data for a complete experimental description of this type of motion so far as the forces involved are concerned. Under the

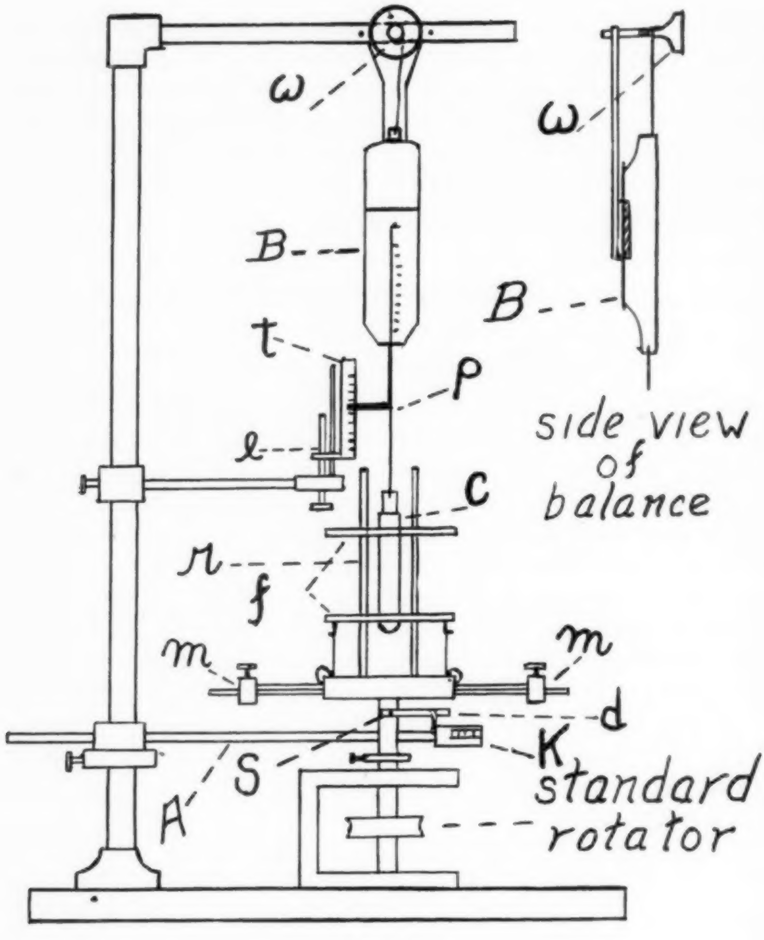

FIG. 1.

DIAGRAM SHOWING ARRANGEMENTS OF APPARATUS

W—SCREW ADJUSTMENT FOR SPRING BALANCE.
B—SPRING BALANCE.
T—RADIUS SCALE.
E—SCREW FOR RADIUS SCALE ADJUSTMENT.
P—INDEX FOR INDICATING RADIUS.
C—BALL BEARING COUPLING.
R—UPRIGHTS.
F—FLANGES.
M—ROTATING MASSES.
D—STRIKING ARM FOR COUNTER.
K—COUNTER.
S—ROTATOR SHAFT.
A—SWINGING ARM CARRYING REVOLUTION COUNTER.

stimulus of the desire to obtain such a device the apparatus used in this experiment in the Reed College laboratory has undergone a process of evolution which now seems to be fairly complete in its more important features, although as will be seen the product is as yet a somewhat crude and unfinished mechanism.

The apparatus as now used is illustrated in Fig. I. The friction drive rotator carries rotating weights *m* which slide on arms and are attached to a spring balance through the coupling *C* as shown. As the apparatus stands the rotating parts were taken from one of the older pieces, the only change being to remove the balancing weight and add the coupling. The coupling itself is made from an old bicycle pedal cut down and with the flanges drilled to slide on the uprights. The essential feature is, of course, the ball bearing which prevents the transmission of the motion of rotation to the balance. The forces are measured with an ordinary spring balance. The coupling is joined to the balance by a cord or fine wire carrying an index *P* which moves over the centimeter scale *t*. The displacement of this index when the apparatus is in operation indicates the amount by which the radius has increased and if a proper adjustment is made, so that the initial reading is equal to the distance of the center of mass of the bodies *m* from the axis when at rest and drawn completely in, the radius may be read directly from the scale *t*. The necessary initial adjustment is made by means of the screw *e*. The flexibility is still further increased by suspending the balance from a screw as indicated so that it may be readily raised or lowered.

The method of manipulation and the taking of observations are extremely simple. Consider first the case in which the speed of rotation and the rotating masses remain constant. Here we are to find the relation between the radius of the circle in which the masses move and the centrifugal forces when other factors are constant. The first step is to measure the distance of the center of gravity of the masses *m* from the axis with the apparatus at rest and to set the scale *t* to correspond with this reading. The standard rotator is then adjusted to give the speed desired and the driving motor started. The rotating bodies move out to some position of equilibrium and readings of the two scales give the corresponding values of radius and force. A turn of the screw *W* raises or lowers the balance, the rotating masses at once take up a new position of equilibrium and a second set of readings is obtained.

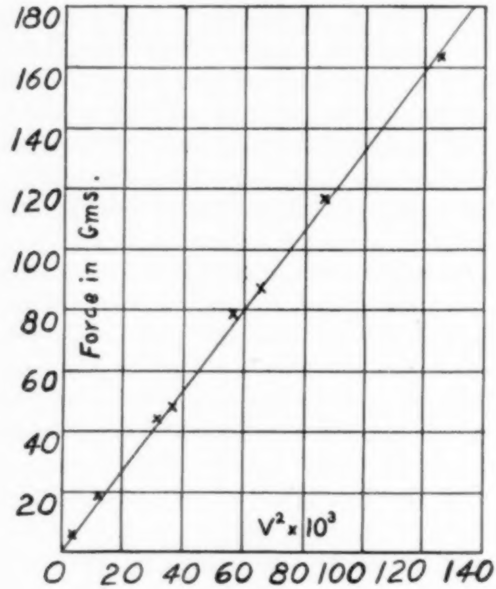

FIG. 2.

RELATION BETWEEN SPEED OF ROTATION AND CENTRIFUGAL FORCE. SPEEDS ARE IN R. P. M. MASS AND RADIUS CONSTANT.

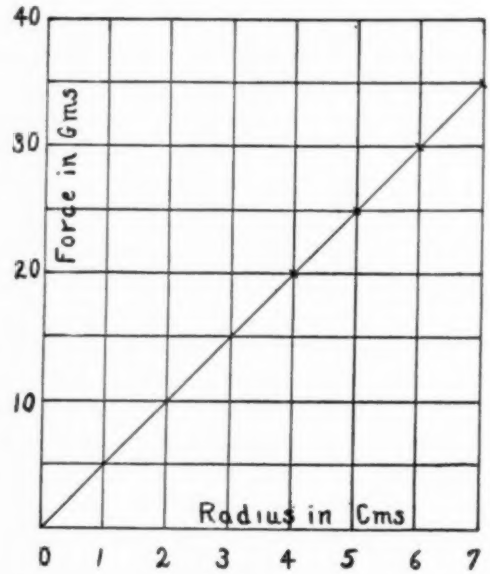

FIG. 3.

RELATION BETWEEN CENTRIFUGAL FORCE AND RADIUS. MASS AND SPEED OF ROTATION CONSTANT.

In case it is desired to keep the radius constant and vary the speed of rotation it is only necessary to adjust the friction wheel on the rotator, determine the speed with a revolution counter and stop watch, raise or lower the balance by means of the screw *W* until the index *P* marks the desired radius and read the balance.

As at present used the variation of the masses is the least satisfactory determination since the only means of doing this is by the rather cumbersome process of removing one pair of bodies and replacing them with another which requires a redetermination of the initial correction on the radius scale. More over the number of changes possible is limited by the number of sets of masses provided.

The character of the results obtainable is shown by the curves which are plotted for the three cases. The data for these graphs was taken in about an hour.

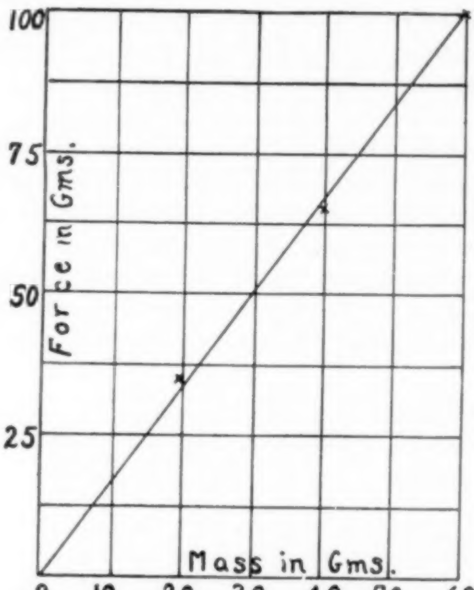

FIG. 4.

RELATION BETWEEN CENTRIFUGAL FORCE AND MASS OF ROTATING BODIES. RADIUS AND SPEED OF ROTATION CONSTANT.

Teachers to the number of 114 from British overseas dominions, Canada, Australia, South Africa, and New Zealand, are teaching this year in schools of Great Britain, and the same number of teachers from England and Scotland have gone to replace them temporarily, under the plan for teacher exchange arranged by the British League of Empire.

THE PROBLEM OF METHOD IN ELEMENTARY BIOLOGY.

By G. W. Hunter, Ph.D.
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In a recent article[1] I called attention to certain investigations begun by me in 1917 which had for their purpose the betterment in methods of teaching biology in the DeWitt Clinton High School, New York City. An active and energetic corps of 19 teachers of biology, a large and well organized school, the grouping in classes of students of approximately equal mentality, and the cooperation of the principal, Dr. Francis H. P. Paul, rendered it possible for the department to make some real experimental contributions to the teaching of elementary biology.

A plan of considerable comprehensiveness was worked out; four teachers undertook experimental studies while the entire department sat in as critics at departmental meetings. While only two papers[2] [3] on the findings were actually published, a good deal of material is now available which has lain fallow since the World War put an end to the experiment. Shortly after my return from war work I went into college teaching. The three teachers who were working with me soon separated, two going to other schools. Hence their work was never collected and published. And until recently there seemed but little reason to use the collected material. But recent articles by Downing,[4] [5] Cooprider,[6] [7] Cunningham,[8] [9] and others make it worth while to publish certain of my findings because of the interesting angle they have on students' interests in methods of doing science work.

After obtaining experimental evidence of the apparent superiority of the *oral demonstration* method over the *laboratory method* with *printed directions* (see [3]) I decided to obtain the reactions

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[1]"The Laborary Attack," *General Science Quarterly*, May, 1927.

[2]"The Collecting Instinct," *General Science Quarterly*, 1919.

[3]"An Experiment in the Use of Three Different Methods of Teaching in the Classroom," School Science and Mathematics, Dec., 1921, Jan., 1922 and Feb., 1922.

[4]"A Comparison of the Lecture-Demonstration and the Laboratory Methods of Instruction in Science," Elliot R. Downing, *School Review*, Nov., 1925.

[5]"Individual Laboratory versus Teacher Demonstration," Elliot H. Downing, *General Science Quarterly*, Jan., 1927.

[6]"Oral versus Written Instruction and Demonstration versus Individual Work in High-School Science," J. L. Cooprider, School Science and Mathematics, Dec., 1922.

[7]"Laboratory Methods in High-School Science," J. L. Cooprider, School Science and Mathematics, June, 1923.

[8]"Under what Conditions, in High-School Science, is Individual Laboratory Work Preferable and When Does the Lecture Demonstration Give Better Results?" Harry A. Cunningham, The Proceedings of the High School Conference of Nov. 18, 19, 20, 1920, *University of Illinois*.

[9]"Laboratory Methods in Natural Science Teaching," Harry A Cunningham, School Science and Mathematics, Oct. and Nov., 1924.

of the students taught on this point. Accordingly at the close of the semester, when we had our classes intact but with very little real work to do, a questionnaire was given to all students taking elementary biology. This sheet, a copy of which follows, was intended to check on a number of points largely dealing with the interests of our pupils.

QUESTIONNAIRE TO PUPILS TAKING BIOLOGY.

School.......................Age............ Sex.....................Date............

Do not sign your name. Be honest in your answers. Think what you want to say before you write it on the paper.

1. Have you always lived in this city? If not tell where you lived before you came here and how old you were when you came to live here.
2. (a) Are you NOW interested in living plants or animals?
   (b) If so, tell how your interest expresses itself. E. G., if you are interested in pets, etc., this would be one way in which this interest would express itself.
3. Were you interested in plants or animals before you were twelve (12) years old?
4. Have you ever or do you now collect, pictures, stones or minerals, flowers, etc.? If so, please tell how you became interested in this pastime.
5. In order of your choice (as 1st, 2nd, 3rd), name three topics which interested you most in your year's work in biology. Tell why these topics interested you.
6. Which way do you like to learn biology best? Put a check after your choice. Please give a reason for your choice.
   (a) by experiment or laboratory work you did yourself.
   (b) by demonstration or experiments performed by the teacher.
   (c) by field or museum trips.
   (d) by class discussions on assigned lessons.
   (e) by reference or outside reading.

Even in the present day of guidance and testing, I am still a believer in Herbert. And as a teacher I was most concerned in the interests of the children whom we taught. Were their interests in subject matter determined to any extent by the environment in which they lived? Were their interests in methods of doing (study interests) well marked? Were such interests different in schools in other environments from that of New York City? Were the interests dependent upon the age of the child? These and many other questions were under discussion by our department. So with these ends in view the questionnaire was placed in the hands of all pupils taking biology.

To make the matter concrete let us take the method of distribution of the questionnaires in the DeWitt Clinton High School. At the end of the first year of biology (first year of four year high school), two or three days elapsed at the end of the term when no assigned home-work was given. Textbooks were taken up, and the boy was made to feel that his work for the year was over.

At this time the teachers of biology were instructed to talk over with their pupils, the value of student opinion of the various courses in the first year, and especially of biology. They were told that biology was relatively a new science, and that its methods were as yet imperfectly worked in the high school. They were then given the questionnaire face down, with instruction to use as much of the 40 minute period as they needed in filling it out. They were urged to be honest in their answers and to give criticisms of a sort that might be used by the department. Inasmuch as they did not sign their names they could say what they pleased and were asked to give unfavorable as well as favorable criticisms.

I passed from one room to another on occasions when these papers were given out, and in almost every instance the boys seemed to be working independently and were seemingly in earnest.

A subsequent examination of thousands of answers of questionnaires convinces me that the answers were honest and showed the best judgment of the boy or girl at the time the answer was given. Of course exceptions were found; such papers as appeared upon reading to be frivolous or nonsensical were at once discarded, as well as papers that did not show signs of intelligence. When introspection on the part of the pupil was required, the answers had a surprisingly genuine ring. In attempts at self analysis the answers of necessity were not always lengthy nor were they expressed in anything but crude and simple language. But in the great majority of cases, evidences of honest reasoning were shown. Very little copying was detected in any of the papers; where it was noticed the papers were discarded. In other words, if the questionnaire method is safeguarded and used under control, it would seem to have some distinctive value in a study of this kind.

Letters were sent out to a number of schools, the courses of study of which were known to the writer. These schools were selected with the idea of obtaining answers from several different schools having different environments, but giving the same type of course to students of approximately the same age. From an urban population were the DeWitt Clinton High School, Manhattan (boys), Wadleigh High School (girls),[10] and the Barrenger

[10]Several hundred answers from Wadleigh High School unfortunately were mislaid and were omitted from the data which follows. I hope to go over these and publish any material which may be of interest at a later date.

High School, Newark (mixed). For rural conditions, I had answers from high schools in Pittsfield, Mass., Brookline, Mass., Montclair, N. J., Plainfield, N. J., and a small rural high school in central New York. By far the most answers considered are from the DeWitt Clinton High School.

Of nearly 5,000 pupils to whom the questionnaire was given, over 4,000 were boys. The ages ranged from 12 to 21 years. In the DeWitt Clinton High School where biology was studied during the first high school year, the median for the age group was 15 years plus. In the schools outside of New York City where biology was studied the second year the median for the age group was slightly above 16 years.

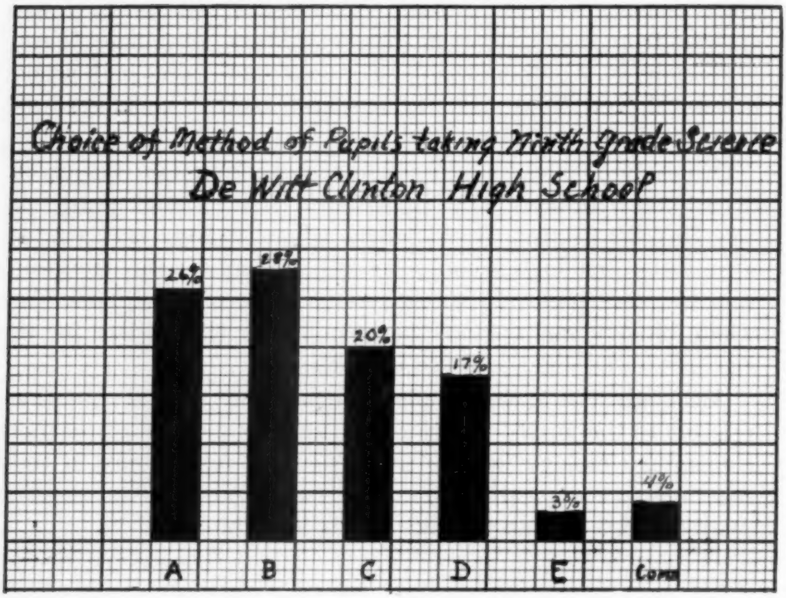
Although the questionnaire touched on several questions relating to the pupils' reactions to different aspects of teaching elementary biology, we are at present interested only in their reactions to the question on methods of learning. This question read: "Which way do you like best to learn biology?"

(A) By experiments or laboratory work you did yourself.
(B) By experiments performed by the teacher.
(C) By field or museum trips.
(D) By class discussions on assigned lessons.
(E) By reference or outside reading.
Give a reason for your choice.

Of 2910 answers used from the DeWitt Clinton High School 775 (26%) chose method "A"; 815 (28%) method "B"; 586 (20%) method "C"; 515 (17%) method "D"; and 86 (3%) method "E." 19 A+B; 23 A+C; 24 B+D; 23 A and others; B 30 and others; 14 A+B+C, or a total of 133 (4%) scattering.

At first thought one might wonder just why this distribution of answers appears, especially as our ideals of science instruction have been based upon methods of pure induction, the method of the self performed experiment. Yet here we have a very large number of ninth year boys giving their preference for the demonstration method. If the child believes in the experimental method, we should expect to have the curve skew more sharply on the first method of learning. To be sure the second method, demonstration by the teacher, IS the experimental method, but seemingly robbed of its great assets of initiative, self-activity and motivation.

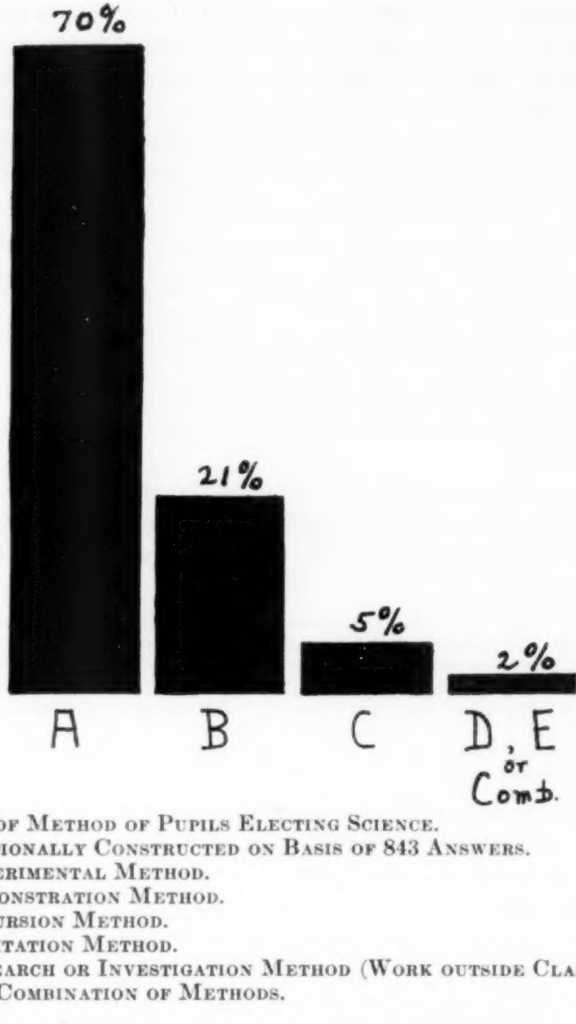
Wishing to test out the matter more completely, I distributed a second questionnaire, which was given to pupils in the second,



A—Experimental Method.
B—Demonstration Method.
C—Excursion Method.
D—Recitation Method.
E—Investigation Method.
Comb.—Combination of Methods.
Proportionally Constructed on a Basis of 2910 Answers.

third and fourth years of high school, who *elected* science. That is, the picked students who, after their course of preliminary training in science, had found the experience worth while from THEIR standpoint, and had decided to go on, were given an opportunity to tell the ways in which they liked best to study science.

In response to the question on method of doing work, we find the following interesting answer. Of 842 pupils answering 593 or 70% give method "A" as their preference as against a little more than 28% of the first year boys. The total results of their answers give method "A" 593 (70%); method "B" 182 (21%); method "C" 48 (5%) and 20 (2%) scattering votes for other methods or combinations of methods. No doubt, the difference in these results may be due in part to the slight difference in the wording of the question which throws the choices naturally into one of three, or rather one of five methods. But on the other hand the difference noted in emphasis cannot be due to that alone.



CHOICE OF METHOD OF PUPILS ELECTING SCIENCE.
PROPORTIONALLY CONSTRUCTED ON BASIS OF 843 ANSWERS.
A—EXPERIMENTAL METHOD.
B—DEMONSTRATION METHOD.
C—EXCURSION METHOD.
D—RECITATION METHOD.
E—RESEARCH OR INVESTIGATION METHOD (WORK OUTSIDE CLASSROOM.)
COMB.—COMBINATION OF METHODS.

My next thought was to see if the choice in methods of doing might be correllated with the age of the individuals answering. This was not clearly answered, partly because the war put an end to this work and partly through the misplacing of a large number of the questionnaires. A computation based on about 700 answers of the 9th year, DeWitt Clinton boys shows a slight age correllation, however. Method "A" appears to be most popular with boys of 17 while method "B" is most popular with the younger boys. The excursion method "C" presented a fairly uniform curve for all ages, while methods "D" and "E"

were chosen by the older boys of the group. These incomplete findings I hope will be finished later upon the recovery of the lost papers. But the findings given above are extremely suggestive and exactly what we should expect.

Let us next examine some of the reasons given in the choice of method "B" as compared with reasons given for the other choices. The following answers are typical:

"Teacher can demonstrate better than the pupil." "Teacher knows more." "Teacher's experiment correct." "Teacher's explanation better." "Better done and understood." "Better and clearer explanation." "Can be done more quickly and explained better." "Understood better." "Clears up doubts and fixes firmly in mind." "Made it clearer to me." "Facts more clearly impressed and not forgotten."

All of the above give good and sufficient reasons, from the standpoint of the child who has not yet learned to work independently.

If we now compared with some of the answers given in favor of method "A" or the experimental method, we find some excellent reasons given for the use of the experiment on the part of the pupil.

"Pupil working himself learns more." "Remember better (longer) things you do yourself." "Experiments interesting." "When you do a thing yourself, you get it better." "Like to do things myself." "Take a deeper interest in things you do yourself." "Easier and more interesting." "Learn more and don't forget." "Understand it better if you do it yourself." "Know it better." "Believe results you do yourself." "Makes a boy think better." "Learns how to do things." "Enjoys it." "Think I learn more." "Sees it clearer." "Seeing is believing."

Some of the reasons given for the choice of the field trip show that other factors than merely a good time are at work. Among the answers are the following:

"Sees things studied about." "See things as they are." "Sees the real thing." "*Sees for self*, apt to remember better after seeing real things." "Sees for self with own eyes." "Seeing is believing." "Shows natural things." "Enjoys trip, learns from nature." "Sees things in their real surroundings." "Found more than a book can give." "Gives close study." "Objects closely observed." "Gives new points in biology."

Anyone reading the above cannot escape from the belief that these answers are honest, and moreover that they are based on excellent psychology. This feeling is borne in a perusal of the answers under "D," the class discussion as a method of learning. Some of the answers follow:

"Makes things plain." "Clears up doubts." "Can correct wrong views." "Understands better by discussion." "Better explanation obtained." "Gives chance for thought." "Get various opinions." "Learns more fully about topics." "Pupil studies lesson, teacher reviews it, and pupil gets it better." "A little knowledge from every boy helps him most."

In the last method of learning, by means of outside reading or outside sources, the more mature mind speaks. "One gets details about things; becomes familiar with new discoveries."

Surprisingly few of the questionnaires given to the DeWitt Clinton boys showed evidence of careless or facetious answers. And the answers on the whole show a surprising sense of educational value in method chosen on the part of the boy. Most of them have very definite reasons for liking a given method and are willing to put themselves on record for it in no uncertain terms.

This whole hearted willingness to give evidence for a chosen method of doing was also evident in the answers of the older boys who elected science. Here the majority of the answers were in favor of the method of the personally worked out experiment. Some of the answers follow:

"Understand better and remember longer." "Chance to do things myself." "Can learn more by doing things yourself." "Understand more thoroughly." "Remember better through personal experience." "Teachers when they do the experiment do the thinking, while the fellows listen and do not understand." "You understand what you do yourself." "The satisfaction of being able to use and play with the constituents of nature which ordinarily seem extremely mysterious." "Felt proud to be able to do such things." "Experiments done by myself led me to take a broader view of many things." "Do it yourself, you are interested." "In this way I learned all the chemistry I know." "Let the pupil think the thing out for himself." "If we do it ourselves, we learn much more than by watching the teacher do it." "We can see what we are doing, we cannot always see what the teacher does." "Personal experience makes a deeper and more vivid impression than a mere knowledge of the facts gathered out of books, or a knowledge gathered from the instructor."

It will be noted that these answers show more thought and maturity of judgment than those of the ninth grade pupils. If we can measure the growth of power in boys, it would seem that here we can see it, and that here is evidence that science has done its share in aiding in thought processes. Many of the answers are so good pedagogically that they might have been taken from some modern book on educational psychology. And yet we say that children do not think.

It is evident, not only from a comparison of answers of the questionnaires, but also from the number of boys electing that the older boys chose methods of learning that involve more self reliance and more self-activity than the beginners in science. They prefer the experimental methods. And we find that contrary to the methods advocated for the secondary school, the

method of science in its pure inductive form is not so well fitted to beginning student's use as we used to believe.

An interesting comparison of city and country children can be made, both because of the differences in environmental conditions which make field work and work with living things in their natural habitat an essential part of the courses.

In the outside schools, we have results based on about 900 answers. In the papers used we find the following choices: "A" 225 (25%); "B" 186 (20%) "C" 262 (29%); "D" 134 (15%); "E" 22 (2%); and 71 (8%) having combinations of methods. At once we note the difference in emphasis of choice of the pupils, the methods of learning by means of the field trip coming out in first place, learning by experiments self performed second, the demonstrations by the teacher, third, classroom recitations, fourth, and the reference or research method last. It is interesting to note that the age distribution of this group is slightly older than in the case of the DeWitt Clinton boys. This may be a factor in the choice of method if our observations on DeWitt Clinton boys amount to anything.

A graph made to integrate age correllation with method was again made for this group on a proportionally computed basis. A noteworthy difference showed itself. A large number of the younger children preferred the field excursion; the demonstration method was, on the whole, preferred by those of 14 and 15 years, the experiment and recitation showed rather flat curves, and the outside reference method was again preferred by more of the older pupils.

The reasons given for choice of the various methods of learning are interesting reading. Among the reasons for method "A" (the experimental method) we note the following:

"If so done I understand work better, it is more firmly impressed, fixed more firmly in mind." "Interesting to watch and see results." "Just enjoy it." "Remember them better." "To do a thing yourself is more instructive and interesting." "Interesting and impresses one deeply." "Learn more from own experience than others." "Easiest and most fun." "More interesting and easier done." "Absorb more and understand better." "One has real things to work with." "Remember better when work it out by self." "Like to find things out by self." "More interesting and easier to remember." "Remember them better because I wrote them out." "More interesting, doesn't know why." "Look up details yourself and remember them." "Easier to remember." "Interesting to do them yourself." "Learns more."

Method B (demonstration method).

"Understands better this way." "Much clearer." "Comes clearer." "Easier to understand." "See the things done without hard work." "Interesting and makes work clearer." "Get a more thorough recitation in

class after seeing experiments." "Understand it better by watching the experiments." "We are given a chance to witness the different experiments and note the results." "You learn more from teacher than from book." "Interesting and make things clearer." "After the experiment I was more certain of my lesson." "More interesting than to do it myself." "Teacher knows more than we do." "No important point omitted." "Best understood." "Know what is done." "Teacher makes it interesting." "Hard points explained." "Teacher better fitted to work and explain it."

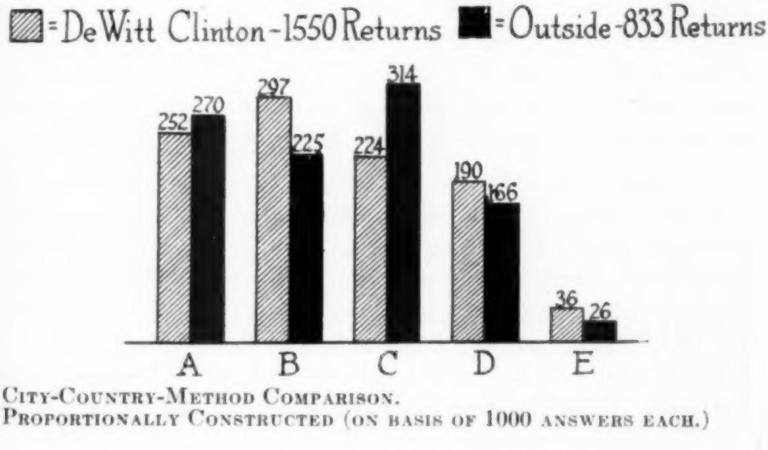
Reasons given under the "C" (field trips) are as follows:

"Larger field than text." "Natural surroundings." "Study better in nature's surroundings." "See objects at home." "See them in their homes." "Remember longer by seeing." "Knowledge gathered from objects sticks." "See actual real things." "Real specimens impress student." "Great chance for collecting." "Out of doors life fine." "Enjoys a trip." "Native environment interesting." "See (observe) things as they are." "Likes to see things." "Get more ideas from trip than by making experiments." "Get closer to nature." "See nature in its natural form." "Interest and pleasure combined." "Likes country." "Likes collecting, especially when guided." "Brings in new things from out of doors."

Among the answers given "D" (class discussion method) we have:

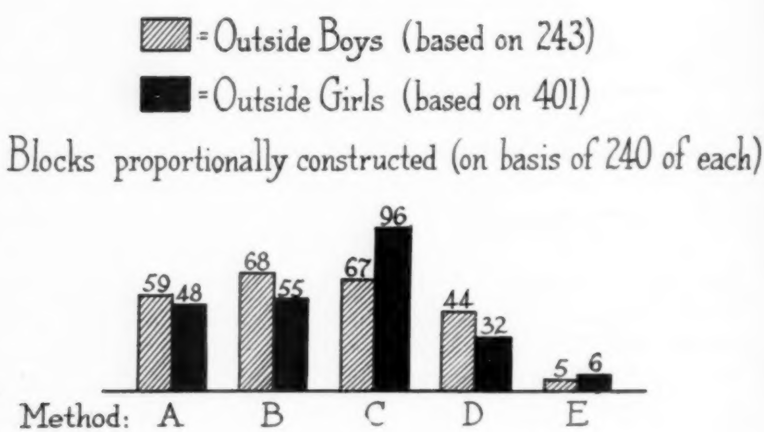
"Hear every one's contribution." "Clears ideas." "Clears up hazy ideas." "Points not clear brought out in class." "Get an idea first by self, and then have it clinched." "Errors corrected and explained." "New views presented." "Learn more from general discussion." "Helps you understand it." "One learns from another." "Get other points of view." "Likes to take part herself." "Broadens views, new points brought up."

It might well be argued that the country pupil would be more self reliant and also better equipped to choose methods which involved more individual thinking and more self-activity because of his contact with the living things in his environment. As a matter of fact we have already noted some of the answers given in favor of a chosen method of doing which seem to indicate this



City-Country-Method Comparison.
Proportionally Constructed (on basis of 1000 answers each.)

to be to a degree true. A comparison of the choice of methods of doing based on 1550 returns from DeWitt Clinton and 833 returns from outside schools give the following interesting comparison. The answers were compared by construction block graphs based on 1000 answers. On this proportion of every 1000 boys in DeWitt Clinton, 252 chose method "A"; 297 method "B"; 224 method "C"; 190 method "D," and 36 method "E." Outside the city, out of every 1000, 270 children would choose method "A"; 225 method "B"; 314 method "C"; 166 method "D" and 26 method "E."



As we would rather expect the field excursion leaps into prominence in the country, with the individual experimental method in second place. In the city school the demonstration method is ahead of all the others, and the field trip or excursion method drops to third place. Evidently the environment plays a part in the choice of methods. Possibly also the children from the outside schools used in the questionnaire represent a picked group of higher mentality than those in DeWitt Clinton.

The choice according to the sex of the pupils was next investigated to see if this would throw any light on the results obtained in the schools outside of New York. The following interesting graph shows why the excursion method was more popular in the country schools. On a basis of 240 each, a proportional block graph was constructed from the choices of 243 boys and 401 girls outside of New York City. The graph speaks for itself. While the boys have little differences in choice between

the demonstration and excursion method, the girls on the other hand prefer the excursion method, the demonstration and experimental methods following in the order named. The total number of girls preferring the excursion method is almost as great as methods "A" and "B" combined. Investigation of the reasons for this choice show the "picnic" element and the collecting of flowers, leaves or animals play an important part in determining the choice of girls for the excursion method.

Conclusions.

The matter of choice of method of doing showed interesting differences between city and country pupils. Five methods of doing were enumerated by the questionnaire, "A" Experimental method (by pupil); "B" Demonstration method (by teacher); "C" Excursion method; "D" Classroom discussions; "E" Outside reading or investigation. The most city children (27%) chose method "B," while the most country children (29%) chose method "C." A study of the graphic results shows that the girls of the non-urban schools were responsible for this choice of the excursion method.

A comparison of pupils studying elective science with those who are taking first or second year science shows an astonishing change in the method of attack. The older boys prefer the self-active experimental method and give excellent reasons for their choice, while the younger show a tendency to prefer the demonstration. In the older boys *electing* science, 70% choose the experimental method against 21% taking the demonstration method. These results seem to point out the fact that our methods in the elementary and secondary schools differ too greatly, and that we must attempt to modify the methods of each if the step from one school to another is to be successfully taken. The Junior High School movement is evidently sound.

A slight age correlation with choice of method was noted. Careful study showed the more mature pupils chose methods "A" or "E," the younger preferring "B," "C" or "D." The reasons for the choice show that the younger pupil is not yet ready for the pure inductive method and still relies on the teacher's authority and wants help. This fact should be borne in mind by all thinking teachers who plan courses in elementary science.

As has been pointed out girls' preferences in method showed less reliance in self and more interest in nature as seen by the preference for field trip.

A DEVICE TO AID IN GENERALIZING GEOMETRICAL IDEAS.

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A proposition in mathematics is a general statement of a truth to be demonstrated or an operation to be performed. The figure or figures which illustrate it however must necessarily be drawn in a definite way. Some minds have trouble in passing from the particular to the general and the truth is thought of as more or less limited in application to the particular diagram used.

In order that all possible cases coming under the hypothesis may be examined the various parts of geometrical figures should be regarded as expanding and contracting. Doesn't part of the pleasure in studying geometry come from the discovery that amid the changing sizes and shapes considered there are certain unchanging relations? The simple apparatus described below may be used to supplement the ordinary methods of teaching geometry by showing the various cases that may come under one general statement.

A board about $2\frac{1}{2}$ feet square and $\frac{3}{4}$ inch thick is perforated by $\frac{1}{8}$ inch holes 2 inches apart. One side, shown in the figure of this article, is used for propositions involving the straight line and circle. The other side is exactly like it except that there is no circle attachment and it is used for propositions concerned with straight lines only. To represent a straight line of variable length, elastic bands about 3 inches long and $^3/_{16}$ inches wide are used. They may be fastened together by a square knot. Three connected bands are sufficient when stretched to cross the board. A supply of these, two bands joined, and single bands will give all required straight lines. The ends of these bands are fastened to the links of chains of the size ordinarily used for fastening the outlet plug to a wash bowl. The links of a piece of chain may be easily opened, separated, and closed again. The free end of a band is fastened to a link by a square knot. A number 14 casing nail in any hole of the board will hold a link in place. A drop of solder near the middle of the nail will prevent it from going too far through the board. Bands stretched and fastened by links to nails represent straight lines. If desired, the ends of the lines may be indicated by large letters cut from insurance calendars or from cardboard. By holes punched through them these letters may be hung from the nails. Moving a nail and the attached line and letter from one hole to another, any desired position of a line may be shown.

A circle of variable size is represented by an 8 foot length of band saw with the teeth ground off. It bends into an almost perfect circle. A block, E, about 3 inches square and 1 inch thick holds it in place. This may be made in two parts about equal in size. One end of the band is fastened to the back of the top of the lower section. A groove cut in the back of the lower part of the upper section should be large enough to admit loosely the free end of the band. Both sections are fastened to the board in the position shown in the figure. The band is bent and the free end run through the groove. By pushing or pulling on the end F a circle of variable size may be represented. If desired the block can be made movable and the center of the circle always located at the center of the board.

When the board is vertical the weight of the band causes a sag which is inappreciable up to a diameter of about 18 inches. For larger circles a nail may be placed in a hole under the lowest part of the band and the circle adjusted in size so that practically all the sag is taken up. When the board is horizontal the band is sensibly circular for all diameters.

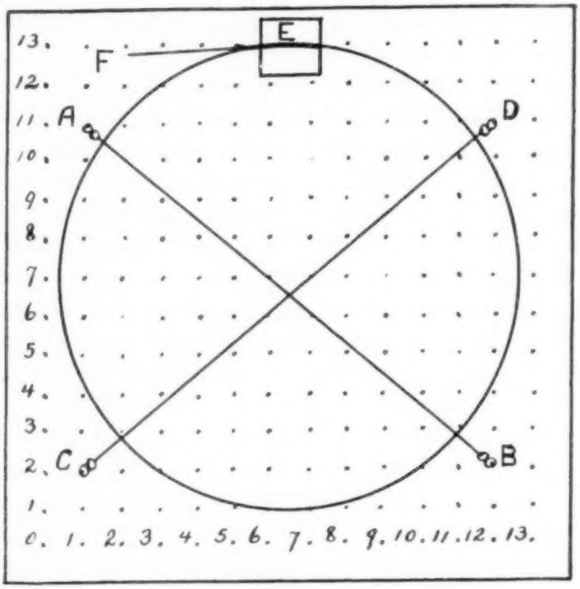
As only the straight line and circle are treated in plane geometry practically any proposition may be set up with the apparatus just described and changes made to adapt the figure to special cases. A few illustrations follow.

Take the proposition often given as the first in the text book, "If two lines intersect, the vertical angles are equal." Using the side of the board not having the circle attachment set nails at points, as at A, B, C, and D in the figure. Attach rubber bands as shown and a particular figure will be set up. Pupils may be asked if the proposition seems to be true for this position of the lines. By moving the nails at B and D with the attached links and bands to other points, the truth of the statement may be seen for any other special position of the lines. The special case where all the angles are right may be noted. Some texts in order to have pupils see the necessity for logical proofs give figures showing the danger of trusting the eye. But where possible should not the truth be approached intuitively as well as logically? "Does this seem to be right"? is a question which may often be profitably asked in a mathematics class. It whets the appetite for a logical proof.

To illustrate the different classes of quadrilaterals and how one variety shades off into another by limiting the definition, stretch bands between nails placed as indicated below or in any

other suitable positions. By sticking pins at the designated points in the figure the changes may easily be followed.

Trapezium, (2, 4), (4, 8), (9, 10), (10, 4).
Trapezoid, move (9, 10) to (9, 8).
Isosceles trapezoid (9, 8) to (8, 8).
Rhomboid, (8, 8) to (12, 8).
Rectangle, (4, 8) to (2, 8) and (12, 8) to (10, 8).
Rhombus, (2, 8) to (5, 8) and (10, 4) to (7, 4).
Square, (2, 4) to (5, 3) and (7, 4) to (10, 3).



To develop the ideas of constant, variable, and limit place nails at A (2, 2), B (7, 2), C (12, 2). Stretch bands between each pair of points. Move the nail at B toward (7, 12) stopping at various points to show that AB, BC, angles BAC, BCA, and ABC are variables; that AC, the difference between AB and BC, the difference between angles BAC and BCA are constants. Show also the limiting values of the base angles and of the vertex angle.

To illustrate the use of the circle attachment take the theorem "In the same circle if two chords are unequal, the greater chord is at the less distance from the center." Stretch a band from point (0, 0) to point (0, 13). Move the nail at point (0, 0) to the right across the board. As the line becomes tangent to the

circle the value of the chord is zero. As the line approaches the center of the circle the chord is seen to become greater until it reaches its maximum length, the diameter of the circle. As the line moves away from the center the chord becomes smaller passing through the preceding series of values in reverse order. By using circles of various diameters the truth of this proposition and of the following ones may be seen to be independent of the magnitude of the circle.

"An angle formed by two unlimited intersecting lines which meet the circumference equals either the sum or the difference of half the central angles on the intercepted arcs, according as the point of intersection is within or without the circle." By choosing properly the points on the board the following special cases may be set up and their relationship shown: angle at the center, inscribed angle, angle formed by two intersecting chords, tangent and chord, tangent and secant, two tangents, two secants. The auxiliary lines used in the proof may be shown and their change is interesting as the various cases pass through their limiting positions to other cases. If two bands are attached to a nail, and the nail moved along a semicircumference while the bands pass through the ends of the semicircumference, the eye can readily recognize the right angle formed in every position of the nail.

"If a pencil of lines cuts a circumference, the product of the two segments from the vertex is constant, whichever line is taken." The following special and limiting cases may be shown; vertex within, on, and without the circumference, secant and tangent, two tangents.

HOOKE'S LAW AND JOLLY BALANCE SPRINGS.

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Purdue University, Lafayette, Ind.

Joseph O. Thompson, of Amherst College, has shown, in an article published in "Science" of September 24, 1926, that small silver, copper, steel and brass wires give an elastic lengthening increasing more rapidly than the stretching force. He called attention to the fact that American text-books, intended for college use, are teaching that "elongation is closely proportional to the stretching force" whereas, it is only roughly proportional.

The writer has noticed the same careless practice in laboratory

manuals for college use in regard to spring performance. They teach that the stretch of a spring is proportional to the stretching force regardless of the kind of spring used. As a matter of fact, the conical shaped spring is the only kind which performs in that manner.

The reason for this error in the teaching of spring action, no doubt in many cases, is ignorance on the part of the authors. In order to make this matter clearer, some data are presented here which were obtained from two springs belonging to a Jolly balance. One of them is a straight helical spring, while the other is a conical one.

The coils of the conical spring are small at the top and increase in diameter regularly towards the bottom, giving a cone-like appearance to the spring.

The straight helical spring does not follow Hooke's Law, while the conical one has been so designed that it will follow the law.

The following data were taken to show that straight helical springs do not stretch proportional to the stretching load.

STRAIGHT HELICAL JOLLY BALANCE SPRING.
Mass. of Spring mo—8.7 gms.

Load m.	Stretch	Stretch per gm. wt.	Period T	(Period)^2 T^2	(Period)^2 / gm. effective mass
gms. wt.	cm.	cm.	sec.		$T^2 / \left(m + \frac{mo}{3}\right)$
10	8.43	.843	.668	.4462	.0345
20	16.77	.838	.884	.7814	.0341
30	25.08	.836	1.053	1.1088	.0337
40	33.38	.834	1.201	1.4424	.0336
50	41.62	.832	1.327	1.7619	.0333
60	49.77	.829	1.443	2.0822	.0331
70	57.90	.827	1.545	2.3870	.0328
80	66.01	.825	1.640	2.6890	.0324
90	74.04	.823	1.728	2.9859	.0322
100	81.92	.819	1.810	3.2761	.0319
110	89.92	.817	1.886	3.5569	.0317
120	97.93	.816	1.955	3.8220	.0311

Some manuals and text-books teach that one third of the mass of the spring should be added to the suspended mass in calculations for kinetic energy and period of oscillation, in the case of a mass suspended from the end of a straight spring and made to oscillate up and down. For a detailed treatment of this see "Analytical Mechanics" by Dadourian, p. 327.

This treatment is based upon Hooke's Law and upon an

assumption that the coils of the spring are all the same distance apart. Neither one of these assumptions being true, the treatment is not strictly correct.

According to this deduction, the square of the period should be proportional to the effective moving mass $\left(m+\frac{mo}{3}\right)$. The data show that this relation, $T^2 \Big/ \left(m+\frac{mo}{3}\right)$, is not followed. It shows, also, that Hooke's Law is not followed. See column "Stretch/gm. wt."

The following data were taken to show that the conical spring, when correctly designed, will stretch proportional to the stretching load. It also shows that the square of the period of oscillation is proportional to the effective moving mass.

However the fractional part of the mass of the spring which goes to make up the effective moving mass is not one third, but about 0.365 for this particular spring.

Conical Jolly Balance Spring.
Mass of Spring mo—8.2 gms.

Load m.	Stretch	Stretch per gm. wt.	Period T	(Period)² T^2	(Period)² / gm. effective mass
gms. wt.	cm.	cm.	sec.		$T^2 \Big/ \left(m+\frac{mo}{2.73}\right)$
1	4.45	4.45	.822	.6756	.169
2	8.92	4.46	.912	.8317	.167
3	13.37	4.45	1.000	1.0000	.167
4	17.82	4.46	1.084	1.1750	.168
5	22.28	4.45	1.166	1.3590	.170
6	26.84	4.45	1.238	1.5276	.170
7	31.18	4.45	1.304	1.7004	.170
8	35.65	4.45	1.368	1.8714	.170
9	40.13	4.45	1.430	2.0449	.170
10	44.47	4.45	1.490	2.2201	.170
11	48.92	4.45	1.544	2.3839	.170
12	53.38	4.44	1.598	2.5536	.170
13	57.82	4.45	1.656	2.7423	.171
14	62.28	4.45	1.704	2.9036	.171
15	66.72	4.45	1.756	3.0845	.171
16	71.18	4.45	1.796	3.2256	.170

The conclusion is that straight helical springs should not be used in experiments on Hooke's Law and Simple Harmonic Motion. Attention should be called to the fact that conical springs for Jolly's Balance are especially designed to follow Hooke's Law.

A FLEXIBLE WORKING DEVICE FOR THE USE OF LIBRARY REFERENCES.

By Esther A. Trainor,

Barbour Intermediate School, Detroit, Michigan.

In order to make the aims of science a reality and to put correct methods into practice, it is necessary for the teacher to have a wide knowledge of the book materials within the reach of the pupil, and to have that material so classified as to make it available at all times. This necessitates an intimate acquaintance with all the library books upon the science shelves, the accomplishment of which must carry over and stimulate a higher grade of class-room teaching and pupil response. I shall endeavor to outline a practical working device useful and valuable to any science teacher. This may be obtained as follows:

1. Procure three-by-five inch cards and a case in which to keep them in file.
2. Index and group according to units, and an accurate and speedy reference is always at hand.
3. Tabulate the problems and text book references by name and pages on the cards. Since each unit has a number of problems set forth to be solved, and their solution is one of the pupils' goals, it is most convenient and necessary to know where their solution can be found in text book and in library.
4. Learn what the library has to offer and tabulate accurate references found there.
5. Tabulate also a list of suitable experiments and class room demonstrations that will fit the unit.
6. Make separate records on cards of such references as give suitable materials for special topical reports.
7. Add to these records as new books are placed upon the science shelves, so as to keep the card system up-to-date.

When a special phase of a subject is brought out and there is a class interest or an individual interest to be satisfied, the card indexes will be found to be a time-saver and ready reference to draw upon. Simply hand the child or a group of pupils the card or cards with the required references for their needs and under a selected leader send them to the librarian. There they procure their books with no loss of time and solve their problem. These ready references of suggestive topics will always result in an eager response. This stimulates science reading and inculcates a deeper interest in science that can not fail to broaden the knowledge and experiences of the pupils.

I shall now quote a few of many available and suitable references that are applicable to the general science outline, and which will show two typical units in the outline.

HOW A GOOD WATER SUPPLY IS OBTAINED.

A. Class room texts:
 1. Hunter and Whitman (community), pp. 146-158.
 2. Hunter and Whitman (home), pp. 77-89.
 3. Trafton—Science, pp. 45-51.
 4. Barber—Science, pp. 381-427.
 5. Van Buskirk and Smith—Science, pp. 68-95.

B. Library References:
 1. Purification of Water:
  a. Chemistry of Familiar Things, Stadtler, pp. 93-97.
  b. Essentials of Chemistry, Hessler and Smith, pp. 57-59.
  c. American City Magazine, March, 1924, pp. 243.
 2. Pumping Stations and Pumps:
  a. American City Magazine, Nov. 1923, pp. 462-478.
  b. American City Magazine, Oct. 1923, p. 267.
  c. General Science, Clark, pp. 189-197.
 3. Filtration of Water:
  a. Compton's Pictured Encyclopaedia, pp. 3703-3704.
  b. Hand Book of Health, pp. 85-87.
 4. Filtration and Chlorine Versus Typhoid:
  a. American City Magazine, Nov. 1923, pp. 507-508.
 5. Hydraulic Ram:
  Boys' Own Book of Science, Darrow, pp. 170-173.
 6. Water Supply:
  a. Checking the Waste, Gregory, pp. 86-122.
  b. Everyday Science, Snyder, pp. 198-206.
  c. American City Magazine, March 1924, pp. 241-245.
  d. Romance of Modern Engineering, Williams, pp. 366-377.
  e. Commerce and Industry, J. R. Smith, pp. 185-190.
  f. Detroit's City Supply—Year Book, 1923.
  g. The Land We Live in, Price, pp. 188-190; 234-235.
 7. Chlorine Treatment of Water:
  Foundations of Chemistry, Blanchard and Wade, pp. 164-167.
 8. Properties of Water:
  Everyday Science, Snyder, pp. 136-141.
 9. Springs and Artesian Wells:
  a. Romance of Modern Engineering, Williams, pp. 366-377.
  b. Hand Book of Health, pp. 81-88.
  c. General Science, Snyder, pp. 196-198.

C. Experiments and Projects for Home and School:
 1. Boys' Own Book of Science, Darrow:
  a. Test for hard and soft water, pp. 109-113.
  b. Make a sand filter, pp. 94-96.
  c. Distill water, pp. 97-106.
 2. Everyday Science, Snyder.
  Effect of Varying Temperatures, pp. 136-144.
 3. Trace hot and cold water system.
 4. Inspect faucets.
 5. Demonstrate, "water seeks its own level."
 6. Read home water meter.
 7. Keep records of meter readings.

HOW OUR CLOTHING IS MADE AND HOW IT IS KEPT CLEAN.

A. Class room texts:
 1. Van Buskirk and Smith, Science, pp. 286-306.
 2. Hunter and Whitman (Home), pp. 219-237.

B. Library References:
 1. Silk:
  a. Secrets of Everyday Things, Fabre, pp. 20-21.
  b. Story Book of Science, Fabre, pp. 99-103.

c. The Story of Silk, Bassett.
d. The Study of Fabrics, Turner, pp. 66-89.
  1. Artificial fabrics, pp. 86-89.
e. How the World Is Clothed, Chamberlain, pp. 105-127.
f. Textiles and Clothing, M. C. Gowan and Waite, pp. 155-183.
g. Shelter and clothing, Kinne and Cooley, pp. 171-184.

2. Leather:
  a. American Inventions and Inventors, Mowry, pp. 164-171.
  b. How the World is Clothed, Carpenter, pp. 147-156.
  c. Everyday Mysteries, Abbott, pp. 146-162.
3. Rubber:
  a. Wonder Book of Rubber, chapters I to XIII.
  b. How the World Is Clothed, Carpenter, pp. 240-261.
4. Thread:
  a. How We Are Clothed, Chamberlain, pp. 154-156.
  b. Secrets of Everyday Things, Fabre, pp. 3-7.
5. Cotton, Lisle and Mercerization:
  Textiles and Clothing, McGowan and Waite, pp. 77-80.
6. Wool:
  a. Secrets of Everyday Things, Fabre, pp. 25-46.
  b. American Inventions and Inventors, Mowry, pp. 158-162.
  c. Shelter and Clothing, Kinne and Cooley, pp. 148-170.
7. The Evolution of Clothing:
  How the World Is Clothed, Carpenter, pp. 10-14.
8. Cotton:
  a. Story Book of Science, Fabre, pp. 71-76.
  b. American Inventions and Inventors, Mowry.
  c. Study of Fabrics, Turner, pp. 1:29.
  d. Textiles and Clothing, McGowan and Waite, pp. 59-99.
  e. Shelter and Clothing, Kinne and Cooley, pp. 97-130.
  f. How the World Is Clothed, Carpenter, pp. 14-50.
9. Minor Vegetable Fabric:
  How the World Is Clothed, Carpenter, pp. 66-73.
10. Flax and Hemp:
  a. Secrets of Everyday Things, Fabre, pp. 31-36.
  b. Study of Fabrics, Turner, pp. 90-103.
  c. How the World Is Clothed, Carpenter, pp. 50-65.
  d. Shelter and Clothing, Kinne and Cooley, pp. 131-147.
  e. Textiles and Clothing, McGowan and Waite, pp. 59-99.
11. Adulteration of clothing;
  a. Shelter and Clothing, Kinne and Cooley, pp. 194-199.
  b. The Study of Fabrics, Turner, pp. 79-86.
12. Calico Dyeing and Printing:
  a. Secrets of Everyday Things, Fabre, pp. 59-76.
  b. Study of Fabrics, Turner, pp. 98.
  c. Textiles and Clothing, McGowan and Waite, pp. 78.
13. Removing Stains from Cloth:
  a. Shelter and Clothing, Kinne and Cooley, pp. 319-331.
  b. The Study of Fabrics, Turner, pp. 118-126.
14. Bleaching, Bluing and Starching:
  a. Introduction to Science, Clark, pp. 158-167.
  b. Foundations of Chemistry, pp. 170-171.
15. Hargreave's Spinning Jenny:
  Textiles and Clothing, McGowan and Waite, pp. 32-44.
16. The Invention of the Cotton Gin:
  a. American Inventors and Inventions, Mowry, pp. 148-152.
  b. Leading American Inventors, Iles, pp. 75-83.

C. Class Experiments:
  1. Test Clothing for Adulteration:
    a. Shelter and Clothing, Kinne and Cooley, pp. 194-99.

b. Study of Fabrics, Turner, pp. 79-86.
2. Tests with Acids and Bases:
   Boys' Play Book of Chemistry, Yates, pp. 79-91.
3. Remove Stains:
   Study of Fabrics, Turner, pp. 118-126.
4. Test Materials for Wool by Burning:
   Boys' Own Book of Science, Darrow, pp. 127-35.
5. Soap—Make Soft Soap:
   Test Soap for Borax:
   a. Boys' Own Book of Science, Darrow, pp. 119-126.
   b. Everyday Mysteries, Abbott, pp. 42-50.

Since such a card record as this is a flexible one, it can be used advantageously in review of any particular unit, or when studying a unit that is clearly related to one that has previously been studied. For example, it will be found expedient to review or closely relate the unit on "How Better Plants and Animals are Bred" with the unit "Domestication of Plants and Animals," since they overlap in some instances. Another example of related over-lapping subject matter will be found in the two units "Plants and Their Relation to Human Welfare" and "Bacteria." In such cases, the shifting of card references will be found useful, especially if they contain notes as full as can be made on each subject. I have found them almost indispensable in my own work, since nothing else gives so speedy a solution to every day science needs.

REVIVES "DEAD" HEARTS.

A "heart hormone," a physiologically powerful chemical compound secreted within the living heart and acting to keep it beating ceaselessly, has been discovered by Dr. Ludwig Haberlandt of the University of Innsbruck. It is to be classed with the secretions of the ductless glands, such as the thyroid in the throat and the adrenals near the kidneys, which have far-reaching effects in the lives of men and animals, and some of which are now widely used in medicine.

Prof. Haberlandt states that the existence of some such internal chemical stimulus to action had long been suspected, because frequently hearts removed from the bodies of animals kept on beating outside, which they would not have done had the stimulus been supplied by the nervous system alone. He found that extracts from a portion of the heart of the frog would act on the stilled heart removed from another frog, causing it to contract again. The extract was able to cause this reaction even in hearts that had been lying still in glass dishes for as much as three and one-half days.

A similar extract from the hearts of dogs, having comparable effects, has been obtained in Brussels by Dr. J. Demoor, and is cited by Prof. Haberlandt as proof that his "heart hormone," as he has named the compound, is of general occurrence among vertebrates and of physiological importance to warm-blooded animals.

The Austrian physiologist is of the opinion that his newly discovered hormone may come to have considerable importance in medicine, as a stimulant to weak hearts. He points out that an abundant supply is easily available, in the hearts of animals killed for meat in the packing houses.—*Science News-Letter.*

COMMON FALLACIES IN REASONING MADE BY PUPILS IN GEOMETRY.

By Truman P. Sharwell, A.B.,

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The errors in reasoning made by our pupils in geometry might be grouped roughly under three classifications as follows:

(1) Assuming the converse. This error goes back even as far as Pythagoras, for he thought that the converse of every proposition is true. An effective way that I have used in presenting the idea that not every true statement is reversible is to present to the class the following statement and ask whether it is true: "A horse is a four-legged animal." Now reverse it in the form "Every four-legged animal is a horse" and ask the same question. This simple discussion is needed when the class reaches the proposition, "If two angles of a triangle are equal, the sides opposite these angles are equal."

(2) Reasoning in a circle. This is a frequent source of error. It usually consists in assuming in the proof the very thing the pupil is trying to establish. It is well to guard against this error early. This can be done by presenting to the class a proof involving this error and having the class criticize the proof. Reasoning in a circle also occasionally (particularly in the case of repeaters) takes the form of using in the proof a proposition that occurs later in the sequence and thus has not yet been proved.

(3) Making use of a *non sequitur* in the argument. (a) One form this takes is the drawing of conclusions from a special figure. For example, the pupil may draw an equilateral triangle when a scalene triangle is called for, or a square instead of an irregular quadrilateral or instead of a more general parallelogram or rhombus. It is well to work out with pupils in advance as part of the introduction to demonstrative geometry the idea that the given data rather than the figure should be the basis for argument. (b) Pupils in trying to prove triangles congruent sometimes try to use two sides and an angle which is not the included angle. (c) In giving a reason for the equality of two angles which lie in different triangles, pupils sometimes quote the proposition, "If two sides of a triangle are equal, then the angles opposite the equal sides are equal." (d) Pupils in

drawing construction lines are inclined to "overwork the line." They assume that certain things follow from a construction that do not follow from the construction. This error is usually first met when the class comes to the first proposition on isosceles triangles. This error should be prepared for in advance by a series of exercises.

SOME CURIOUS EFFECTS OF A ROTATING MAGNETIC FIELD.

By N. F. Smith,

The Citadel, Charleston, S. C.

A common form of apparatus for demonstrating the principle of the induction motor consists of a field ring having a two-phase or a three-phase winding which, when connected to a suitable source of power, produces a rotating magnetic field whose frequency is the same as that of the current used. While experimenting with a two-phase field-ring, some very peculiar effects were observed which, while really very simple, appeared rather puzzling until a suitable explanation was formulated. These effects have doubtless been observed by many others, but, so far as the writer has been able to discover, no discussion of them has been published. The following facts were observed:

The field ring was mounted in a horizontal position and supplied with two-phase alternating current, producing a rotating field. If a squirrel-cage rotor is mounted within the ring it rotates in the direction of rotation of the field at nearly synchronous speed, in accordance with the well-known law of induction motor action. An aluminum disc, or a compass needle mounted over the ring rotates rapidly in the same direction, When, however, a glass plate is laid on top of the ring, and iron filings are sprinkled over the surface of the plate, the filings are seen to whirl rapidly *in the opposite direction*, i. e., contrary to the direction of rotation of the magnetic field. The reason for the unexpected reversal in the direction of rotation of the iron filings was made the subject of a systematic study.

The first step was to place the disc or the compass needle beneath the center of the field ring. The direction of their rotation was the same as before, as was, of course, to be expected. When, however, the glass plate was placed beneath the ring, and iron filings sprinkled on it, they rotated in *the same direction* as the compass needle. The same experiments were tried with a

three-phase field ring supplied with three-phase current. All the results were exactly the same.

The next experiment tried consisted in mounting a large bar-magnet along the diameter of a metal disc of non-magnetic material. The disc and magnet were then rotated rapidly in a horizontal plane by a motor-driven rotating machine. The same experiments were carried out with the rotating field produced by the rotating magnet, and in every instance the results were the same as before. The compass needle and the aluminum disc rotated in the same direction as the rotating magnet. The iron filings rotated in the opposite direction when sprinkled on a plate above the magnet, and rotated in the same direction when the plate was placed below it.

It was not until a bar-magnet was moved slowly by hand under a plate on which iron filings had been sprinkled that the true cause of their peculiar motions was ascertained. The explanation arrived at is as follows:

As the magnet pole is moved along under the plate, it magnetizes the filings in its immediate vicinity as it approaches them. These filings attract other filings near them, and they form in small columns along lines of force coming from the magnet pole. As the magnet pole moves rapidly along, these columns assume positions which are at every instant tangent to the lines of force from the pole. Thus as they are passed by the pole, they are turned completely over in a direction opposite to that in which the pole is moving. This is crudely illustrated in the series of drawings of figure 1, in which the lines of force are represented by dotted lines, and successive positions of the miniature magnets composed of the fillings are shown as the magnet pole moves to the right. If the pole is moved slowly, these miniature mag-

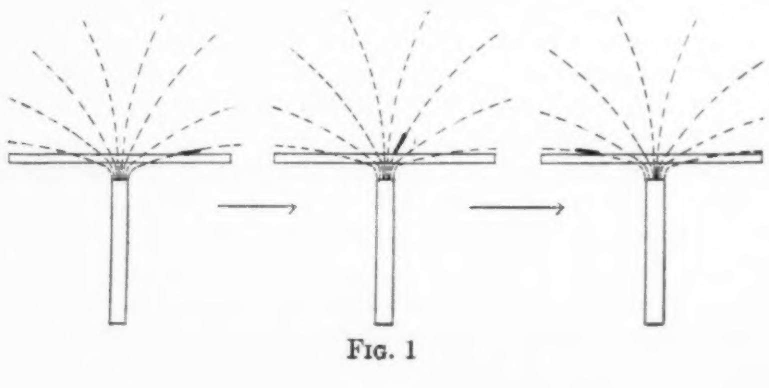

FIG. 1

nets will be dragged along after it when they are directly over and perpendicular to the surface of the plate. But, due to the strength of the field, they acquire considerable momentum as they approach the moving pole, and because of the high velocity of the pole, this momentum carries them on in the same direction after the pole has passed. They are thus thrown back, away from the pole, and are quickly beyond the influence of its field. The next approaching pole produces the same effect and the process repeats itself again and again, the filings moving in an apparently steady stream around the plate in a direction opposite to the motion of the poles.

When the pole is passed along over the plate, the filings become magnetized and arrange themselves as before. The miniature magnets will always set themselves tangent to the lines of force from the pole. In doing so, it is obvious from figure 2 that they

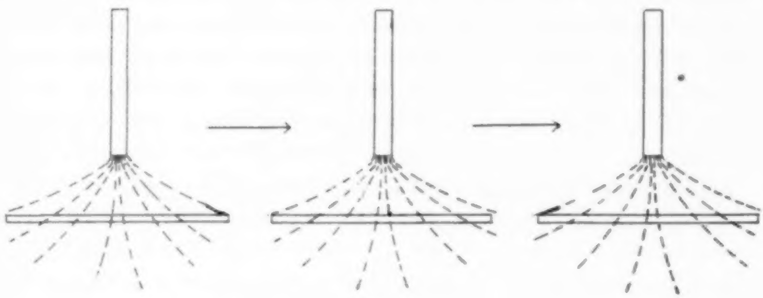

Fig. 2

will roll over on the plate in the same direction as that in which the pole is moving. As each pole approaches and passes a particular group of filings, it rolls the miniature magnet a little farther in the direction of its own motion.

The foregoing observations were made and the conclusions reached by Mr. Daniel Bailey, a student in the Physics Department at The Citadel. It is hoped that the explanation given will remove the confusion and add interest to a most instructive demonstration experiment.

Children of Porto Rico are taught to speak, read, and write in both the Spanish and English languages. More efficiency in English than in Spanish, in both speed and thought getting, was shown in a recent test of reading abilities of pupils in Vieques. The supervisor states that more intensive work is done in English than in Spanish, and that consequently the children are more careful in their use of English.

WHAT, IF ANYTHING, HAS REALLY BEEN PROVED AS TO THE RELATIVE EFFECTIVENESS OF DEMONSTRATION AND LABORATORY METHODS IN SCIENCE—II.

By F. A. Riedel,

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University of Kansas.

A previous article dealt in a general way with the present status of the controversy above alluded to. In the present writing individual studies[1] will be analyzed in some detail, especial emphasis being placed on the weaknesses which place the findings in the class of roughly tentative, rather than highly probable. The writer holds no brief for either side. He is interested in any method or combination of methods which will so teach science that it will function as far as possible in everyday life. In making the criticisms it is admitted that educational research is exceedingly difficult and it is not easy to convince persons not parties to an investigation as to what has really been proved. This is due to the great complexity of human reactions, the mosaic character of abilities and the practical difficulties in the control of class situations without sterilizing and paralyzing them.

The reader is referred to the previous article in the May number of School Science and Mathematics for the list of researches here discussed; also to an article by Dr. E. R. Downing in *School Review*, November, 1925, and to other articles, many of them listed in his article and by Dr. W. D. Carpenter in the *Journal of Chemical Education* for July, 1926, for further references.

It may be argued that if a person assumes the position that the technique of the several researches is so faulty, the tests so unreliable, the populations so small, and the measurement of results so lacking in many-sidedness, it would not be worth while quoting the data on the findings. Nevertheless general experience shows that figures, even if crude, often point to certain tendencies and have some real value. With that point of view, there follows an analysis of the data of the six studies to find what they indicate granted that these be taken at face value. Each study has been reported in our educational press and quite complete reviews have been made of nearly all of these as a group. Their good points have been very well displayed, so that the

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[1]One study reported by some of the reviewers is omitted because of unusual incompleteness of the report.

present writer may be excused if he deals more with the weaker side of the studies individually and collectively.

The first high school study is that of W. H. Wiley, in chemistry. His methods are traceable to the great pioneer work of Ed. Mayman,[2] but he adds certain very commendable features which even at this late date deserve imitation. Wiley's work is now about 10 years old; he worked with very small numbers, only 8 per group; we are shown no samples of his tests; we can only guess at their length and are not shown whether they measure other than information. A modern statistical treatment would disclose whether the reported differences in the averages by either method are significant. Inspection of the individual scores which are so well displayed shows the student groups were not of equal strength, a fact admitted by the author.

His main findings are:

"In every respect the lecture (demonstration?) method is least effective in imparting knowledge to high school students.

"From the point of view of expenditure of time, the laboratory method is the most costly and the text-book the least.

"The different methods show decided individual differences both for immediate and delayed reproduction.

"Probably a combination of the three methods (text, lecture, and laboratory) will give the best results in the teaching of high school chemistry.

"There are *other advantages*, however, that the laboratory method has over the text and lecture method which we cannot consider here. (Italics mine.)

"From the standpoint of hygiene there is no doubt as to the superiority of laboratory methods."

Mr. Wiley's experiment was not repeated by himself or by others. We do not know whether the exercises chosen represent the then or present courses of chemistry. The data are treated in such a novel way that it is hardly feasible to reproduce them.

The study by H. A. Cunningham dealt with biological and chemical facts. He made two studies. We cannot judge to what extent these were on identical matter or by identical method. The results are reported as per cent averages and in line graphs. The display of measured data is quite complete. No samples of tests are given. They were designed to be diagnostic on the laboratory items, "What was done," "What happened," and

[2]Mayman, Ed., New York City Schools, 1915.

"What is the explanation." We cannot judge to what extent the answers to these questions were obtainable through opportunities to see texts, to hear discussions, and to get otherwise ready-made information. A study of the scores discloses the following: (In this and the other studies when percentages are used, a difference of at least 5% is arbitrarily chosen to represent a significant difference between averages running above 50%).

	What Was Done	What Happened	Explanation	Combined Total
Exercises having same score by either method	4	4	1	3
Exercises having higher score by demonstration method	6	6	9	9
Exercises having higher score by laboratory method	2	2	2	0

The average time required for demonstrations was 31 minutes; for laboratory work, 43 minutes. This ranged from differences of 33 minutes to 3.5 minutes in favor of the demonstration method.

In a table of 96 score items there are 9 cases of all students making 100% scores on a given type of material. This shows the material did not really test these cases.

In Cunningham's second study the following data obtain:

	What Was Done	What Happened	Explanation	Combined Total
Exercises having the same score by either method	3	1	1	6
Exercises having higher score by demonstration method	5	7	6	4
Exercises having higher score by laboratory method	3	3	4	1

The average time rquired in this case for demonstrations was 23 minutes, and for laboratory work, 25 minutes. The differences ranged from 18 minutes to 1 minute, in favor of the demonstration method. Here we find no "undistributed" scores. There are no persons receiving 0 or 100% scores.

The scores show differences resulting from either chance, and hence unreliable from the use of too small groups (12 or 13 pupils) or they show that students react with reference to the way in which a given method is suited to them. The data indicate, however, that there are more cases in which the demonstrations are more effective or just as effective as the laboratory work, in so far as the tests reveal differences that are significant

and that represent all desirable phases of learning. Evidently the tests were not satisfactory measuring instruments in the first experiment.

Cunningham concludes:

"It is in the study of individual cases that most real values may be obtained from a study of this kind.

"It is not safe to make sweeping generalizations as to the best method from these data.

"There is a great variation in the scores made by individuals under the two methods.

"A higher per cent of knowledge is retained by the individual (laboratory) method in each study.

"As a rule there are too many variations of individual cases which are covered up in the general results."

Nobody will accuse Cunningham of being unscientific in these well guarded remarks.

The methods and presentation of the Cooprider studies in biology are similar to those of the preceding study. Incidentally this brings to our attention the necessity and the value of uniform methods of displaying the data. While the percentage method, and the use only of averages, rather than range of distribution and median scores have serious disadvantages and are not exclusively used in the latest studies, there is a real advantage in the *uniformity* found.

Cooprider tried to diagnose the learnings in biology in terms of memory, manipulation, observation and reasoning by testing on the items "Object," "Procedure," "Results" and "Conclusions," respectively. In general the same criticisms of the above study apply to his work. Both studies have excellent features. Both made a second study. Both attempted to measure other than mere information. Both tried to control teaching conditions and other valuable factors are to be seen. Nevertheless, the kind of testing and scoring is not evident; the size of groups is too small (14 to 17); the significance of the stated differences is not computed. One has only to examine the well-detailed tabulations to find very marked variations in scores on individual experiments and to notice how competent the averages are to swamp all these probably significant differences.

Examine the following data of the first study: 12 exercises were used, and scored on 4 different phases. *Oral directions* were given.

	Obj.	Proc.	Re-sult	Concl.	Com'd. Tot.
Exercises in which the same score is made by either method	2	8	3	2	6
Exercises in which the score is made higher by demonstration	6	1	6	3	2
Exercises in which the score is made higher by laboratory	4	3	3	7	4

There were 9 cases of 100% scores. The results while widely varying for the different items were added unweighted and averaged, yielding averages of 76.2% for the demonstration and 76.6% for the laboratory method. A reflection on the reliability of such procedure shows its obvious disadvantages. Note that the laboratory method yields apparently significant advantages in regard to "conclusions" which is certainly one of the most valuable parts of the exercises. There are other items which show up better or quite as well by the demonstration method. It is this very discrimination which we must make for the working out of demonstrations and laboratory experiments designed to have the highest efficiency.

In 12 exercises in which *written directions* are given:

	Obj.	Proc.	Re-sult	Concl.	Com'd Tot.
Those with the same scores by either method	4	8	5	4	5
Those with the same scores, higher by demonstration	5	3	5	6	6
Those with the same scores, higher by laboratory	3	1	2	2	1

Here there were eight 100% and three 0% scores.

In the second study we are given only final averages and for obvious reasons we cannot intelligently criticize this work. The scores in general are similar to those of the first study.

Delayed tests, for permanence of retention were given. These resulted in the following:

	Demon-stration	Lab.	% later score is of original Score Demon-stration	Lab.
With Oral Directions:	64.17	65.16	55.82	50.19
With Written Directions:	63.55	60.24	52.95	62.20

It would appear from these data that the type of directions has little influence on the immediate response of pupils in demonstration work; that it makes a probably significant difference in case of laboratory work and that it makes a real difference in

favor of the laboratory work to use written directions for the sake of permanent knowledge.

Cooprider states:

"Demonstration work is better than individual work (1922).

"On the other hand if we wish our students to retain laboratory work, it appears from this study that demonstration work should be given with oral instructions and the individual work with written instructions, also

"Individual work should be given in preference to the demonstration (1923)."

The display of data in all the above cases points to the mosaic character of the abilities of pupils and of separate difficulties of the experiments.

A still different type of work is attempted by Kiebler and Woody. They restrict their study to a limited portion of physics, in fact to a portion with certain very specialized difficulties. To the extent that the study of heat fails to represent the types of ability and of emotional reaction toward studies of light, sound, electricity, etc., it fails to represent all of physics, and the different responses of both sexes. Other studies show marked differences in sex interest in given science subject matter. This is especially true of mechanics. The authors used commendable scientific procedure in attempting to control the teaching conditions and in providing for objective tests. These were varied in form and intent. This study shows the first noted attempt to measure *ability to apply* subject matter. For this, picture tests and actual laboratory situations were used.

Again the averages are expressed as percentages with no indications of the individual scores and variations. We are not told how large the groups are—a most regrettable omission. The groups were equated solely on an intelligence score basis—a not overly safe basis, in spite of the fairly high (about .75) correlation between intelligence and general physics achievement scores. Furthermore it would make a difference as to whether the groups contained the same distribution of intelligence, and whether each group had about the same number of a given sex of the same intelligence. An unpublished study by the writer indicates that it is not at all permissible in certain science experiments, at least, to pair boys with girls of equal intelligence scores, since the factors of interest and experience seem to play a large part.

The authors do not give data to assure the reliability of the tests nor the significance of the differences. The tests are, how-

ever, apparently quite objective and seem to measure more than mere memory. But the form of a test is not sufficient in itself to insure that it measures comprehension, reasoning or ability to apply. That depends on the antecedents and the ongoing conditions. We are not assured that the tests are a valid measure of the learning. That is, we are not in a position to judge whether failure on test items corresponds to failure in life situations or that high success on test items corresponds to success in real situations in like measure.

The reported averages are for demonstration method 60.52%; for individual laboratory method 59.66% for immediate learning. In selected experiments the corresponding averages are 57.86% and 51.7% before the exercises were written up and 77.58% and 75.4% after they were written up. The gains are 19.75% and 23.7%. The gain is somewhat larger in case of the laboratory method.

To use an analysis similar to that employed for the preceding studies:

Exercises with same score by either method	8
Exercises with higher score by demonstration method	4
Exercises with higher score by laboratory method	2

The authors conclude:

"The results of the experiment suggest that in the smaller high school, at least, better teaching would result, and much money would be saved if the laboratory could be arranged and equipped so as to facilitate demonstration of many of the experiments instead of trying to provide apparatus for individual performance of all of them.

"The individual method tended to be superior in those experiments that are especially difficult to perform or in which great care must be exercised to see the exact procedure. Such facts suggest that the *most effective method depends upon the nature of the experiments themselves, and suggests the need for scientifically classifying them* (Italics mine).

"When the demonstration method gives equal or superior results, it is to be preferred to the individual laboratory method because *it saves about one-half of the time usually devoted to performing the experiments and permits the instructor to use the time thus saved in relating the facts and principles* to allied phenomena" (Italics mine).

The work and findings are very suggestive but we do not know how students would react to other teachers, other parts of

physics, and with different kinds, and sizes of apparatus and with other durations of laboratory period. The results cannot be safely applied to all of physics nor can they be applied to other sciences. At best such findings relate only to the specific situation. And they relate to a given type of demonstration and laboratory method. Each of these is capable of infinite variation. It would be well to get data on both methods taught under optimum conditions to disclose their respective contribution to science learning.

Mr. Anibal reports an interesting experiment in chemistry teaching. He is one of those to use larger numbers of pupils per section. This should add to the reliability of his findings. He also specifies the length of laboratory period, the time of day, the interval between experimental sections, the seating of students for demonstration and the similarity of apparatus and procedure. He also uses a superior technique in equating groups. This he does by *pairing* students of like intelligence based on scores of two different tests. However, nothing is said as to whether boys and girls are paired. In small classes of say 15-25 pupils it is difficult to find any person in another group who can be matched with a given one in the first group on more than one basis. However, if results are to be significant we cannot forever ignore this fact. Two persons even of the same intelligence rating are likely to be quite different in their reactions, due in part to the error of the rating, the errors in the experimental reactions and scores, the differences in interest, experience, antecedents and reactions (e. g. mind-set) toward the experiment. It is for this reason that this and all similar researches dealing with small populations are to be considered only roughly indicative of certain trends.

Anibal, in spite of the good features enumerated, unfortunately did not report it as fully on some points as is necessary to carry conviction. Neither this author nor any other before or since has been given space enough to report in such detail that the research could be repeated by others. If this were done we could discover how generally applicable the findings are when carried into new localities and conditions and by different teachers to different pupils. A statement is made as to standardizing a test for the permanent retention, but no statement is made as to how such an elaborate procedure was carried out. In the second trial all but ten exercises were eliminated. We are left with deep concern as to how and why these particular ten

survived. Did they represent chemistry as well or better?

Inspection of the data shows almost identical ranges, medians and averages of scores made by either method. We are left only to presume that the tests covered mere information. There was some difference in the range, median and average of intelligence in each group. But in the "check" or repeated (?) experiment there was a large difference in range, namely 56-90 in the demonstration group, and 35-92 in the laboratory group with corresponding medians of 69 and 75 and averages of 71.11 and 68.05. Note here the misleading effects of averages, when not accompanied by medians and ranges. Similarly the intelligence scores ranged from 68-185, averaging 130.9 for the demonstration group and from 81-186, averaging 127 for the laboratory group. Evidently the groups were not well equated. Comparisons were made by Anibal as to the relation of method to intelligence. The following data are extracted from his tabulations:

	Lower Group	Higher Group
Similar scores by either method	3	6
Superior by demonstration method	2	5
Superior by laboratory method	4	3

It will be seen that slightly more pairs of students do as well or better by the demonstration method, but roughly an equal number do better by one method than by another. The higher intelligence level seems to profit more from demonstrations and the lower from laboratory work. If similar data can be obtained in future researches it would be a valuable contribution to our practice. Only 14 pairs of pupils serve as the basis for these conclusions.

In the retention test the demonstration yielded an average score of 57.5% and the laboratory 60.85%. On the first half of the laboratory year the corresponding scores are 28 and 38. These figures seem more significant. The data are based on 10 pairs.

Anibal concluded:

"The delayed retention is so little different that one method may be considered as good as the other. There was a slight indication that the maetrial was remembered better when taught by the individual laboratory procedure. (Presumably these remarks are meant to be confined to verbal memory and information.)"

An interesting conclusion reached is to the effect that students

were better able to do satisfactory laboratory work when this was preceded by an interval of demonstration work.

Attention is called to the much larger expense and longer time needed for the individual work.

The last of the major studies is that of W. D. Carpenter in chemistry. This study is notable for the large populations, the validation of tests, the wide distribution of schools, the use of many teachers and the use of modern statistical methods for computing averages, distributions and coefficients of reliability. The data are presented in terms not generally understood by the teacher and quite radically different from those of the previous studies. This has the advantage of greater meaningfulness to many who are interested in the technical side of researches, but there is a bare possibility that to the average reader the use of unfamiliar numbers will have unwarranted or "magic" effects and tend to obscure the real values, good or bad, in the research. As presented the individual and group scores are completely swamped by the process of rotation and averaging. The net effect is to show whether there are differences in the methods so large as to overshadow all variables. Further only information with possibly limited ability to think in chemical terms and to apply to new situations is measured here. Whether anything besides the information is measured is not apparent by examination of the tests as has been intimated in another place. There were 3 methods, one by demonstration, one by individual laboratory, and one by group-of-2 which were tested out. The net result is that about as many groups succeeded in one method over the other as by the alternative method. There was a significant deficit of score for the group-of-2 below the individual method. The scores were all reduced to sigma values. By this method a score of zero sigma is the standard score, of -3 sigma is a very low rank and of $+3$ sigma a very high rank. Sigma scores are not arbitrary but function to express the score of a person in a group in terms of the ability of others of the group to react to given difficulties. The underlying assumption is that scores tend to group themselves according to the curve of probability or of a normal distribution. Dr. Carpenter's means (average sigma-score *per person*) are .064, .031, and .064 and the corresponding sigmas of *distribution* (of the respective *groups*) are .98, .99, and 1.02 for the demonstration, individual and group-of-2 methods respectively. The means or averages by being so nearly 0 signify that the distribution of scores about the mid-value

was very symmetrical, with practically equal numbers receiving scores higher than the standard value as those receiving scores below it. The similarity in the sigmas means that the curves of distribution were very similar and that the range of scores was practically the same in each group. The small size of the sigmas means that the large majority (68.26%) of scores were grouped *closely* around the mid-value; the groups being scored on a given method were relatively homogeneous. Any method with outstanding "distributed" difficulty to the students, or any method in which the larger number of students achieve remarkable success would yield sigma scores of larger values if the tests were capable of "spreading" the scores so as clearly to segregate the several student or group abilities. The significance of the differences is found by calculating the "critical ratio." A result of 3 is taken as significant. In the case in hand the ratios are 1.27 between demonstration and individual method, 3.65 between individual and group-of-2 method, and 5.10 between demonstration and group-of-2 method. The first of the ratios is not significant. The last two are.

The chief unfavorable criticisms of this study are made by the author himself who clearly recognized the limitations. There was no attempt at scientific control of the teaching. It proceeded under the usual even if varied conditions of the several schools. The tests were mainly informational; all the individual differences are swamped in the averaging. It is not shown whether the average difficulties, abilities, attitudes, etc., of chemistry as a whole are represented.

Some of the more significant conclusions follow:

"There are *probably other abilities not measured* by these tests or by any tests yet constructed that will rank the individual method higher than the demonstration method.

"We have as yet *no adequate test for scientific attitude, appreciation, manipulative skill in handling apparatas or scientific method of procedure.*

"It is hoped that administrators, as well as class-room teachers of science, will realize that while the studies so far have shown the value of demonstration as a method of instruction for certain abilities, however, *so far as we know now, we must consider the usual laboratory method as one of our most efficient means of instruction.*

"Probably our laboratories can be made to function more efficiently."

At a later date the writer will offer positive suggestions for a uniform and more complete reporting-form for future researches carried out and submitted by class-room teachers and research workers, and will at that time summarize the most valuable suggestions obtainable from all the science learning studies for the use of interested persons. It is hoped that the whole controversy will tend to stimulate all progressive teachers to thoroughly reexamine the facts and observe with scientific care many new facts not yet reported as to the conditions under which the two methods yield optimum returns.

A NEW MERCURIAL BAROMETER, OF UNIQUE DESIGN.

By E. S. Russell,
Cambridge Botanical Supply Co., Waverley, Mass.

Two hundred eighty-four years have passed into scientific history since Torricelli first performed the experiment by which it is shown that the height of a sustained mercurial column is a measure of atmospheric pressure.

Despite the conclusive simplicity of that experiment, to-day repeated wherever physics is studied, beginning students frequently fail to grasp the similarity between the laboratory barometer and the unpretentious glass tube from which it was developed. An explanation may perhaps be found in the evolution of the modern instrument.

Since Pascal's brother-in-law carried a Torricellian apparatus to the summit of Puy-de-Dôme, mercurial barometers have been constructed with tubes of varied size and shape, ranging from the simple to the fantastic. In the interests of accuracy, or of individuality, single and multiple straight tubes, angular, helical and convoluted tubes have been employed. Attempts to magnify the effect of pressure change were responsible for the sympiesometer, the dial-siphon barometer, the three-liquid barometer, Howson's ingenious moving cistern instrument, and others now remembered only as scientific curiosities.

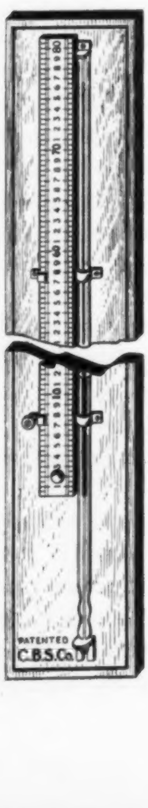
In principle of construction, each of the antecedent types of which record is known, or of which representation is found in historical collections, was a Torricellian tube, communicating with a vessel of mercury. But that vessel, originally a simple well, has now become either the short arm of a siphon, or a closed cistern whose contents are indirectly exposed to the atmosphere.

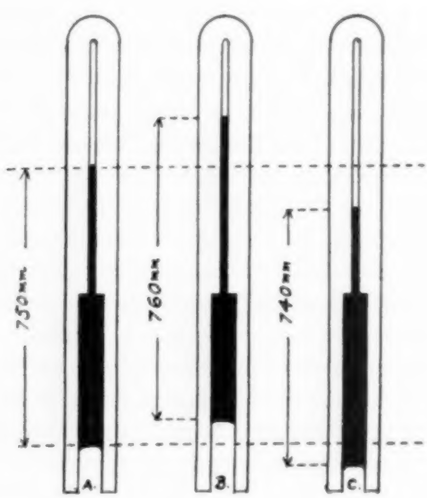
In that cistern lies the zero point of an incomplete scale and (or so it appears) the zero point of the student's incomplete understanding of the barometer.

Unique, therefore, is the recently developed No-Well Barometer which, as its name implies, does not have the cistern common to all other mercurial instruments. Simplicity of design—never a disadvantage from the teaching point of view—characterizes this new barometer.

It consists, essentially, of a straight glass tube, closed at the top; open at the bottom. Its mercury column is directly exposed to the pressure of the atmosphere. Though of uniform external diameter, this tube has a bore larger through the lower 40 cm of its length than that of the upper 60 cm.

As atmospheric pressure increases, mercury from the lower, large bore moves upward into the small bore. The volume of mercury being a constant factor, the total height of the column is thereby increased. Conversely, with a decrease in pressure, mercury moves downward from the small to the large bore—decreasing the total column height. Thus, under any pressure fluctuation, instant response changes both upper and lower





mercury levels, to establish a new, total length for the mercury column. This change in column length is diagrammatically reproduced in the accompanying sketch, in which (with the bore differential intentionally exaggerated) A represents an initial reading of 750 mm; B shows the lengthening of the column at a pressure of 760 mm, and C shows the shortened column at 740 mm.

It will be noted that there is no occasion for human adjustment of the mercury column, which moves only in proportionate response to changes in atmospheric pressure.

Barometric indications being dependent upon the *height* of a mercury column supported, and independent of that column's shape or volume, measurement of the column height gives a true reading. Beside the tube of the No-Well Barometer a full length metric scale is adjustably mounted. When the zero of this sliding scale is set opposite the lower level of mercury, atmospheric pressure is correctly indicated by that division of the scale which stands opposite the upper mercury level.

A student who thus "takes the barometer reading" can scarcely fail to realize that he has done nothing more nor less than to measure the height of a column of mercury, which is obviously supported by the pressure of the atmosphere.

MOST TIME LOST FROM COLDS.

The common cold goes to the head of the list as a cause of lost time. In a survey of absences from work in a big industrial firm over a period of ten years, just completed by statisticians at the U. S. Public Health Service, it was found that colds caused a time loss equivalent to 1.4 days per year for every man on the pay roll, and 2.1 days per annum for every female employee. Colds were directly responsible for 39 per cent of all the absences among the men and for 31 per cent among the women.

Diseases of the general type known as respiratory caused approximately half of all absences but were not so common among the women as the men. Women, it would appear from these records, are more liable to disablement from nervous disorders and diseases of the throat and tonsils, but their disabling illnesses are shorter on the whole than the men's. This condition in favor of the so-called weaker sex is counterbalanced, however, by the fact that their absences were more numerous, totaling 14 calendar days apiece during the whole ten years, while that of the men reached only 8.9.

A high proportion of illnesses occurred among the younger employees, notably among the women. The statisticians suggest that this circumstance may be in part accounted for by the dropping out of the less healthy. The group representing the ages 30 to 35, they state, seems as a whole to have a greater resistance to colds, tonsillitis, and stomach disorders than the younger ages.—*Science News-Letter*.

SOME REACTIONS REGARDING THE PUBLISHED INVESTIGATIONS IN THE TEACHING OF SCIENCE.

I. The Learning Studies.

By Francis D. Curtis,
University of Michigan.

The purpose of this paper is to present some of the more important impressions gained from an analysis of the learning studies[1] in the teaching of science, to mention some of their more striking values and shortcomings as revealed by the published reports, and briefly to discuss the present status of investigation in its relation to future research in this field.

The first learning study in the teaching of science was published in 1910,[2, 3] and since that time more than thirty have appeared. The reports of these range in length from a few paragraphs to entire monographs; and in completeness from brief summaries, incidentally included in longer articles, to elaborate statistical discussions composing the major portions of Doctors' dissertations.

The studies embrace a considerable variety of phases of teaching method and practice, and represent in the aggregate a prodigious amount of time and effort on the part of the various experimenters in their praiseworthy search for objective evidence to replace subjective opinion. They have made contributions which have proved to be, not only of paramount value and importance to the teaching of science, but also of great worth and significance in the development of research in education.

A list of these contributions would include, along with others, the following: Stimulating an interest in the scientific investigation of teaching problems, and creating a desire for more effective teaching; focusing attention upon various methods of teaching, and effecting improvements in classroom procedure; directing attention to practical values of auxiliary devices and materials, and revealing the possibilities of greater economies in laboratory work; throwing more light upon the historical development of scientific experimentation in education, and rendering more intelligent the efforts to unite theory and practice; produc-

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[1] "These studies involve the determination of the relative effectiveness of *different* methods, the determination of the strong and weak points of *particular* methods, and the evaluation of certain teaching devices and practices." Francis D. Curtis, *A Digest of Investigation in the Teaching of Science in the Elementary and Secondary Schools* (Philadelphia: P. Blakiston's Son & Co., 1926), Preface p. v.

[2] J. P. Gilbert, "An Experiment in Methods of Teaching Zoology," *The Journal of Educational Psychology*, I (1910), 321-32.

[3] For digests of twenty-six learning studies published prior to 1925, see Curtis, *op. cit.*

ing a vast quantity of interesting experimental data, and contributing much to the improvement of scientific measurement in education.

Much honor is due to these earlier investigators for their painstaking persistent efforts in a new field under inevitably great handicaps and difficulties. "There were giants in those days," and that their pioneer efforts have not been in vain is evidenced by the fact that remarkable advances and improvements of technique have been shown in several of the more extensive studies reported during the last two years.

But in order that improvement in experimentation may be as rapid as possible, it is expedient to scrutinize the investigations in this field of educational research, for the purpose of noting common or frequently occurring faults which to a greater or a less extent render the findings and interpretations unconvincing. Some, therefore, of the more serious criticisms of these learning studies follow:

1. *Failing to state the problem definitely.* This criticism applies particularly to a few studies, the published reports of which contain no separate statements of the respective problems, but leave the reader to infer these from the descriptions of the experimental techniques employed.

2. *Assuming the equivalence of experimental groups without taking adequate steps to insure this equivalence.* In a number of investigations the experimenters consider the experimental groups equivalent when their *average* mental abilities are equal; nothing in these reports indicates that these pupils were actually paired, or that the groups were equivalent in variabilities.

3. *Securing equivalence of groups upon a basis other than that in terms of which results are measured.* Several examples may be cited in which the experimenters pair their groups on the basis of intelligence, brightness quotient, or mental age, while they base their conclusions upon subject-matter achievement.

4. *Failing to isolate the experimental factor.* One of the older studies has nothing which could properly be termed an experimental factor, while one fairly recent one treats as a unit, an experimental factor which is obviously a composite of two essentially different factors.

5. *Delimiting too rigorously the teaching methods under investigation.* In several studies this is done to such an extent that these methods are utterly different from any used in ordinary classroom situations. The results of such investigations, even

were they totally conclusive and convincing, would be of doubtful practical value, in so far as their legitimate influence upon actual classroom teaching practice is concerned.

6. *Assuming the definitions of the teaching methods under investigation to be standard, i. e., commonly accepted.* The terms, textbook method, lecture method, individual laboratory method, and demonstration method are found in different investigations actually to vary from one another to a greater or less extent. The results of such studies, therefore, even when apparently similar, are actually only slightly, if at all, comparable.

7. *Failing to report the technique in sufficient detail, and mingling findings and conclusions with details of method.* It is difficult or impossible to know with positive certainty from several of the reports what the experimenters actually did. This defect not only weakens the findings and conclusions but renders impossible a repetition of the experiments by other investigators.

8. *Evaluating on the basis of only one criterion, when that criterion is but a single element in a more complex process or situation.* Experimenters have frequently evaluated the relative merits of competing methods in terms of pupils' retention of a knowledge of subject-matter over a longer or a shorter period, and have ignored other goals of instruction, which may be quite as important, e. g., training in scientific attitudes, in reasoning, in correct habits of reaction to given typical situations, etc.

9. *Employing crude subjective tests in measuring results.* This criticism applies not only to the older investigations which were carried out before reliable standardized achievement tests were available, but also to such recent studies as attempt to evaluate methods or devices in terms of learning factors other than subject-matter achievement.

10. *Making gross errors in recording data.* This criticism applies to one investigation particularly, from which the experimenter concludes that one laboratory method is superior to another for securing retention of subject-matter although in different parts of his report, he credits the same average numerical advantage in subject-matter retention to each of the two competing methods.

11. *Including personal opinions among the findings and introducing personal bias into the investigation.* In a few studies, subjective reactions and objective data are combined to a bewildering extent, and in one or more others, the voicing of personal prejudice amounts almost to propaganda.

12. *Making sweeping generalizations from obviously insufficient data.* Examples may be cited of reports in which the experimenters state as of broad application and significance, conclusions and recommendations based upon limited experiments involving only a few, obviously unrepresentative individuals.

To avoid giving undue emphasis to destructive criticism of these investigations, the fact should be stressed that the general criticisms listed above, while worthy of serious consideration, are not peculiar to the studies in the teaching of science, but will be found to apply with equal justice to published learning studies in other fields of education. It is important to keep in mind, moreover, that the merits of these investigations greatly outweigh their demerits, and that these researches lay the necessary foundation for more and better experimentation in future.

It is unwise, of course, to assume that *any* thesis has been yet established beyond question by any or all of these studies, even though, in one or two cases the results may be sufficiently convincing to most students of education to make a repetition of the investigations unnecessary or unprofitable; but the experiments which present the more conclusive and convincing findings are probably not those which are of most importance in classroom practice.

The present incompleteness and inconclusiveness of the results of researches in the teaching of science are well illustrated by investigation into the relative merits of the demonstration versus the individual laboratory methods, the problem to which more learning studies have been devoted than to any other in this field. The available published evidence seems to indicate that the demonstration method possesses a wider usefulness than has formerly been credited to it, and that in general, it imparts several desirable sorts of knowledge, and even some desirable skills, more economically and somewhat more effectively than the more widely employed individual laboratory method. But it would be absurd to conclude from the meagre evidence thus far produced that the demonstration should supplant the individual laboratory method in all branches or in any branch of laboratory science. Teachers of science are doubtless unanimous in the conviction that there is a place for both methods in their teaching, but the question of when and to what extent to employ each method remains for them as far from a satisfactory objective answer as ever.

Some of the obstacles in the way of an early answer to this

question are indicated by a consideration of three of the most important objectives of laboratory work:

1. *Teaching the pupil to manipulate, i. e., "learn by doing."* The chief objective of some exercises is to permit the pupil to "learn to do" in the sense of learning to manipulate. With such exercises it is of paramount concern to keep very clear the fundamentally important distinction between knowing, and thus being able to describe what manipulations are appropriate to a certain exercise, and being able, with dexterity, assurance, and dispatch, to perform those manipulations. Both objectives are desirable phases of "learning to do," but while the pupil may learn by observing demonstrations to know and describe appropriate experimental techniques, or even to make simple, elementary manipulations more or less effectively through imitation, it is difficult to believe that he will acquire any considerable degree of manipulatory dexterity and skill except through the individual laboratory method.

2. *Teaching the pupil to interpret experimental data.* At times the objective is reasoning or interpreting rather than manipulating. The attainment of this objective is usually sought, in physics, chemistry, and biology, at least, through individual pupil experimentation. But in seeking the solution of some problem which has arisen in connection with reading or some vicarious experience, the pupil may find manipulation a hindrance rather than a help to interpretation: His interest and attention may become so absorbed in the details of the investigation that he may lose sight entirely of the main problem to be explained. When reasoning is the prime objective, therefore, experience gained through actually doing may give a less effective basis for interpretation than that gained vicariously through a demonstration, during the performance of which the teacher directs attention to the pertinent, reifying elements.

3. *Teaching the pupil the concept of scientific method.* Again, in a few exercises the objective may be to afford training in the method of the research experimenter, which demands both ability to manipulate and to interpret. It is conceivable that either the individual laboratory method or the demonstration method may further the achievement of this objective, but the objective itself, may be of less value than the preceding ones in a program of liberal, i. e., unspecialized education.

Many problems are implied in the preceding paragraphs, and the aggregate of these with all the others arising from the

various aspects of the learning studies leave the bewildered investigator at a loss to know where to begin. It seems reasonable, however, that for some time to come, investigation in this field should be chiefly concerned with subject-matter learning and retention, because thus far fairly dependable standardized tests are available for subject-matter only; to be sure, commendable beginnings have been made in constructing various tests of power, reasoning, scientific attitudes, persistence, etc., but no test of any of these factors has yet been devised, sufficiently reliable and exact to warrant its use as a "measuring stick" in an extensive series of experiments.

It seems logical to predict, moreover, that in the teaching of science, investigation of the problem of subject-matter learning and retention must finally progress through a hierarchy of three stages, each in turn predominating, but always sharing attention more or less with the other two. These stages of investigation are characterized by the *general aim or purpose served by the separate investigations* composing the respective stages, and not by the degree of refinement of statistical technique or scientific method employed, through the studies must utilize the improvements in statistical technique and scientific method as these evolve:

I. *The stage of general application.* In this first stage, which now predominates, the goal of investigation is to throw light upon the problem of which teaching method, device, or practice most effectively imparts certain *general knowledges, skills, or habits to the average class as a whole.* This stage calls for more studies of the types already attempted, particularly those intended to determine the relative values of classroom methods. But these studies must be sufficiently numerous and extensive to insure a representative sampling of classroom conditions as found in typical American schools.

II. *The stage of more specific application.* This stage grows logically out of the same sort of analysis of all factors as that of the specific laboratory objectives briefly discussed earlier in this paper. It involves, first, the determination of the specific objective which is primarily to be gained from each exercise, subject-matter element, etc., and secondly, the determination, by careful, repeated investigations, of which of the possible methods, devices, or practices best serves the *class as a whole in attaining this specific objective.*

III. *The stage of individualized instruction.* This stage logic-

ally evolves from the second stage and involves the problems arising with individual differences. It may be more specifically defined as the determination of which method, practice, or device insures to *each individual pupil the maximum attainment of a specific objective.* This stage probably marks the ultimate goal of science teaching, the point at which the teacher will be able to say with confidence, that this particular pupil, having these particular characteristics, which the psychologists must first have accurately determined, will gain more of this particular knowledge, skill, or habit from a given curricular element, if taught by this particular method, device, or practice. Such a goal may never be attainable, but nevertheless investigational effort should be directed toward arriving as near to its attainment as may be possible.

The need for more and more experimentation in the teaching of science is patent, but mere multiplication of studies, alone, will not serve. If this research is ultimately to accomplish its purpose, it must be undertaken *only* by educational specialists with specific training for this work, or by capable workers under the personal direction of such specialists in educational research. The scientists, trained only for research in pure science, and the teacher, equipped only with the facilities and the willingness to engage in educational "research," must alike be discouraged from attempting educational investigation; there have already been too many worthless, or even, to the extent that they may influence practice, harmful results of such "investigation." A wider cooperation, however, between the university specialist in educational research and the elementary and secondary school administrator and teacher is necessary; for while a careful worker may require a year or more in which to complete a small learning study, he can, during the same period, efficiently direct a number of other workers engaged in other problems.

But the ultimate completion of even a sufficient number of investigations, alone, will not suffice: A study, however exhaustive its scope, scientific its technique, and significant its implications, attains its full value only when reported in its remotest essential detail of technique and data. The educational magazines have, therefore, a two-fold service to perform: (1) For the benefit of the educational specialist, trained to judge and interpret technique and data, and to ultilize his gleanings for the further improvement of method and the advancement of research, the magazines must be willing to devote to an experiment of

merit, sufficient space to accommodate a full report, even though such practice requires the running of the report as a serial through several issues. Professor Downing is right when he says, "A comparison of results will be facilitated if investigators will publish their results in full."[4] Such a comparison is possible only when the results are published in full. (2) For the benefit of the greater number of teachers and students, interested only in the main points of technique and in the conclusions, the educational magazines must also be willing to publish briefer digests of original reports, which have been published in full elsewhere. Both practices, of course, reduce the number of original articles a magazine may print, but the gain in quality should more than compensate for this loss, especially since there seems to be a growing conviction generally, that one report presenting carefully determined, objective data upon a vital problem, is worth many discussions expressing mere opinions about this same problem.

[4]Elliot R. Downing, "A Comparison of the Lecture-Demonstration and the Laboratory Methods of Instruction in Science," *The School Review*, XXXIII (1925), 688-97.

NEW PHASES OF CHAMBERLIN'S PLANETESIMAL HYPOTHESIS.

Chicago, March.—In his latest annual report to the Carnegie Institution of Washington, and in a recent address before the Geological Society of America, Professor Emeritus Thomas Chrowder Chamberlin, for many years head of the Department of Geology at the University of Chicago, applied the principles of the planetesimal hypothesis to the growth of the earth and to the explanation of its peculiarities, of which he gave a long list.

In his recent studies Professor Chamberlin has tested the planetesimal hypothesis of the earth's origin by following it logically to see whether it would lead to all these peculiar features and elucidate them

The planetesimal hypothesis starts from the simple assumption that a star approached our sun near enough to stimulate, by tidal action, the solar eruptivity and projectivity sufficiently to cause it to project suitable small masses of sun-substance so far toward the passing star that it drew them in the direction of its own motion and gave them revolutional motion about the sun. The recent studies of Professor Chamberlin have made it clear that these projections would rotate on their own axes much as a shell does when shot from a rifled cannon. This rotation would aid in the dispersion of the bolts thus shot out into scattered isolated little bodies revolving about the sun like minute planets (hence planetesimals). The earth's growth was very slow, but was increased by the gradual accessions of the planetesimals.

In the forthcoming issue of the *University Record* further details in the application of the planetesimal hypothesis to the growth of the earth will be given in a summary of great scientific interest.

EXPERIMENT: THE BOILING POINT OF WATER.

By C. J. Peters,

University High School, Columbia, Mo.

Problem: To Find the Boiling Point of Water at Various Altitudes.

1. Look up the barometric pressure at the following altitudes: (a) Denver; (b) Pikes Peak; (c) Mt. Blanc; (d) Mt. Everest; (e) the highest elevation at which records have been made by instruments sent up in a free balloon.

Reference: Physics by Tower, Smith, Turton, and Cope, p. 64; Practical Physics Manual by Ahrens, Harley, and Burns, p. 349. Elementary Principles of Physics by Fuller, Brownlee, and Baker, p. 102.

2. Materials:

(a) Set up your apparatus as shown in the diagram.

(b) You will need the following materials: glass tubing, small beaker, mercury, rubber tubing (soft for joints), rubber tubing (hard for connection to aspirator), thermometer, 100 cc. flask, three hole stopper, aspirator, meter stick, Bunsen burner, clamp, tripod stand, and ring stand with clamps.

3. Preparation:

(a) Fill the flask about half full of water. Put the thermometer in the center hole of the stopper, put an L shaped piece of glass tubing in one of the other holes, and put a straight piece of glass tubing in the other hole. *Make sure all connections are air tight.*

(b) Fill the small beaker about half full of mercury.

(c) Arrange a piece of glass tubing straight about 30″ long with an arm forming an L about 18″ long. Stand it upright in the mercury and secure with the ring stand and clamps. Call this tube M.

(d) Connect the arm of tube M with the straight tube in the stopper of the flask.

4. Manipulation:

(a) Place the flask over the Bunsen burner and bring the water to the boiling temperature. Read this temperature and record. Remove the Bunsen burner.

(b) Read the barometric pressure and record in centimeters.

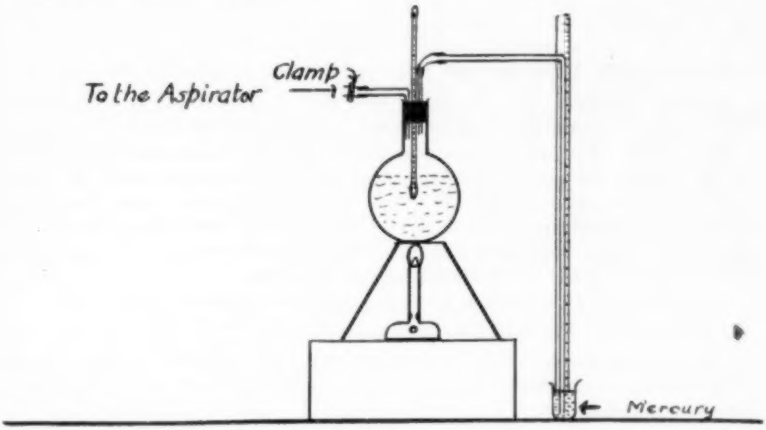
(c) Connect the aspirator with the L tube of the stopper.

(d) Let the water cool 3 minutes from the time of the first reading.

(e) Turn the aspirator on gently and remove the pressure until the water boils again. Close the clamp. Read the temperature,

also the height of the mercury in tube M above the mercury in the flask.

(f) Repeat (e) at intervals of 3 minutes as long as it is possible to get the water to boil.



5. Calculation and Graphs:

(a) You can find the pressure over the water by subtracting the height of the mercury in M above the mercury in the beaker from the barometric pressure.

(b) Make a graph by plotting temperatures on the abscissa and the corresponding pressures on the ordinate.

6. Applications:

(a) Find the point on your graph that has the same pressure as you found Denver to have, and from this determine also from your graph the corresponding boiling point. This will be about the boiling point of water at Denver.

(b) Do likewise for each place designated in 1.

7. Conclusion:

Your conclusion, therefore, will be that the boiling point of any particular place is dependent upon what? And in what way?

MEXICAN GOVERNMENT DIFFUSING POPULAR EDUCATION.

A thousand new rural schools will be established in Mexico by the Federal Government during the coming year, according to announcement of the secretary of public education. As far as possible the schools will be located in sections where the need is greatest. In addition, 10 normal schools will be opened for the training of rural-school teachers, and 10 "cultural missions" will travel through certain sections holding institutes. Each mission comprises a director, a teacher of agriculture, a social worker, and a teacher of physical education, all of whom have undergone a period of special training in preparation for the work. They remain four weeks at each place.

PRIZE ESSAY.

The Rumford Historical Association, Woburn, Mass., cooperating with the American Home Economics Association, offers a prize of *one hundred* ($100) *dollars* for the best essay on "Count Rumford and His Contributions to Home Economics."

CONDITIONS.

Title: Count Rumford and His Contributions to Home Economics.

Subject: Section A. An historical review of "Rumford's Essays" which may legitimately be interpreted as of interest in Home Economics.

Section B. This shall present a list of possible present-day researches in the Home Economics field growing out of a consideration of Rumford's own investigations. This list, it is anticipated, may be of significance in connection with the broadening program of Home Economics Research under the "Purnell Act" and the widening of university, college and business research related to the home.

Competitors: Contest open to anyone.

Illustrations: Allowed, but not necessary.

Length and Form: Not over four thousand (4,000) words. Typewritten, standard sheet, one side only, double spaced, each page numbered, mailed flat.

Disposal: All essays to be sent before October first, 1927, to Miss Helen W. Atwater, Room 617, Mills Building, 700 Seventeenth Street, N. W., Washington, D. C.

Judges: Miss Helen W. Atwater, Editor Journal of Home Economics, Washington, D. C., Chairman.

Dr. Alice F. Blood, Prof. of Dietetics and Director of the School of Household Economics, Simmons College, Boston, Mass.

Professor Carleton J. Lynde, Prof. of Physics, Teachers College. Columbia University, New York.

Enclosures: (a) Author's full name and address typewritten, must be enclosed in a sealed envelope with the manuscript essay. No envelope to be opened until the award is made.

(b) Rejected manuscripts will be returned, if stamped envelope is enclosed.

Publication: (a) Section A of the winning essay shall be copyrighted by and published in the Journal of Home Economics.

(b) Section B from all essays submitted, may, in the judgment of the Contest Committee, be merged into a single list of suggested researches and published by itself.

(c) If likely to prove of general interest, reprints of both "A" and "B" may be sold and the profits be divided equally between the Ellen H. Richards Memorial Fund and the Rumford Historical Association.

References on Count Rumford: Furnished on request to Miss S. Maria Elliott, 120 Charles St., Boston, Mass., when accompanied with stamped, addressed, return envelope.

Committee: Dr. Benjamin R. Andrews, Teachers College, N. Y. Dr. C. Ford Langworthy, Bureau of Home Economics, Washington, D.C. Miss Hughenia McKay, Ohio State University, Columbus, Ohio. Mrs. Ida E. Sunderlin, Pres. Cal. H. Ec. Assn., Inglewood, Cal. Miss S. Maria Elliott, Boston, Chairman.

PROBLEM DEPARTMENT.

Conducted by C. N. Mills,

Illinois State Normal University, Normal, Ill.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem, sent to the Editor, should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to C. N. Mills, Illinois State Normal University, Normal, Ill.

LATE SOLUTIONS.

952. *J. C. Brown, Wheeling, W. Va.; L. R. Kellam, Culver, Ind.*

SOLUTIONS OF PROBLEMS.

961. *Proposed by Orville Barcus, Columbus, Ohio.*

Show that the three numbers are divisible by the same number:

$$21{,}556{,}130^{16}+1,\ 21{,}556{,}127^{16}+1,\ 14{,}370{,}753^{16}+1.$$

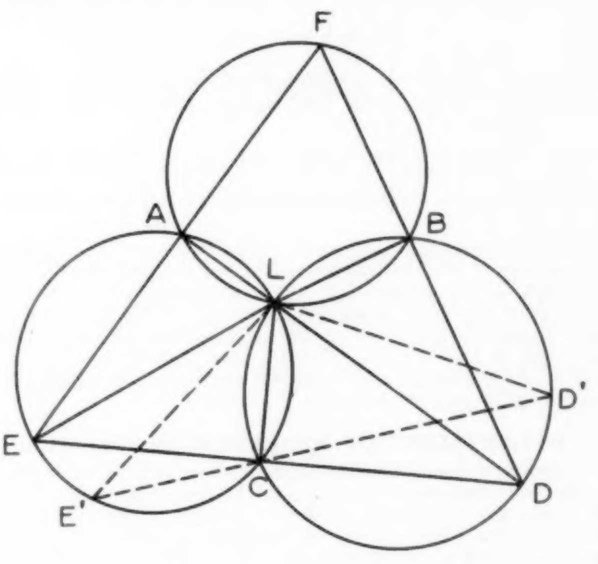
Solved by the Proposer.

$x^{16}+1$ is divisible by $(3x\pm2)$ or $(2x\pm3)$ when $(3x\pm2)=(2x\pm3)=3^{16}+2^{16}=43{,}112{,}257$. Hence x equals 21,556,130, 21,556,127, or 14,370,753.

962. *Proposed by Michael Goldberg, Washington, D. C.*

Construct the maximum equilateral triangle through three given points.

Solved by the Proposer.



Let the given points be A, B, C, Draw a circle through A and B such that AB subtends an angle of 60 degrees. Draw similar circles for BC and AC. Then the largest equilateral triangle is DEF whose sides are perpendicular to the lines joining A, B, C to the point L which is common to the three circles. Let E′D′ be the side of any other triangle. Then

the triangle E′D′L is similar to triangle EDL. But since EL and DL are diameters, E′L and D′L are shorter, and hence E′D′ is shorter than ED.

Also solved by *Bessie B. Green-Andrews, Wichita, Kansas; George Sergent, Tampico, Mexico; Owen Cole, Portrush, Ireland; F. A. Caldwell, St. Paul, Minn.; Smith D. Turner, Cambridge, Mass.*

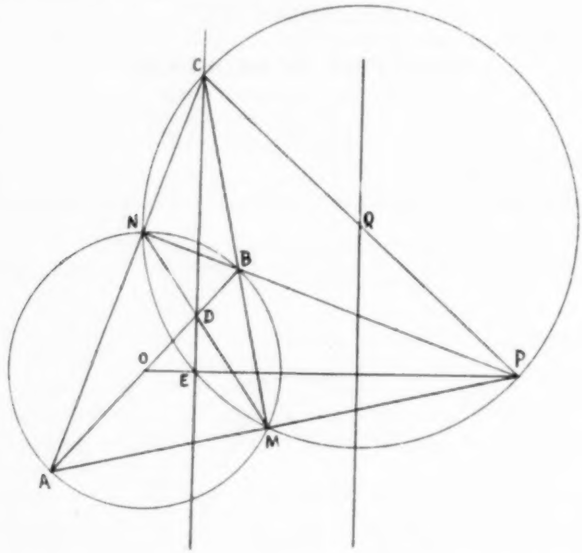
963. *Proposed by J. Murray Barbour, Aurora, N. Y.*

A letter from the proposer states that the problem is not general, and for this reason the corrected problem will be proposed later.

964. *Proposed by Nathan Altshiller-Court, Norman, Okla.*

The lines joining a given point P to the ends of a variable diameter of a given circle, center O, meet the circle again in the points M, N. Prove that the locus of the center of the circle PMN is a straight line perpendicular to PO.

I. *Solved by George Sergent, Tampico, Mexico.*

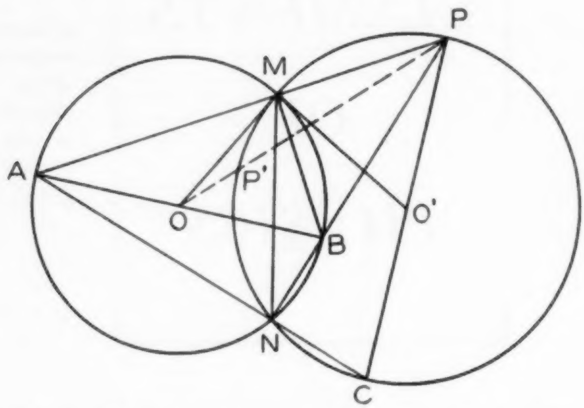


Let AB be the variable diameter, C the intersection of AN and BM. The line through C and the intersection D, of the diagonals of the quadrilateral AMBN is the polar of P. Let E be its intersection with PO. AMB and ANB are right angles. Therefore, PMC and PNC are right triangles. The circle described on PC as diameter passes through M and N. Since PEC is also a right triangle, the circle PMN passes through E, pole of P, a fixed point. Its center is on the perpendicular bisector of the line joining the two fixed points, P and its pole E.

DEPARTMENT OF RESEARCH IN PHYSICS.

The Council and the Educational Committee of The American Physical Society are working on the problem of helping high school and college teachers of physics to advance in their field and to benefit by the work of research physicists. They are recommending a liberal use of this department as one means of attaining their end. Articles will be contributed by members of the Physical Society most of whom are actually engaged in the research work. If physics teachers will write to the editor of this department and tell him of their particular needs, of their interests and, also, of their reaction to the articles that appear, he will be better prepared to present this work to the American Physical Society and to appeal to its members for assistance.

II. *Solved by Michael Goldberg, Washington, D. C.*



In the figure, $\angle OMO'$ is a right angle since $\angle AMB$ is a right angle and $\angle OMA = \angle MAB = \angle MNB = \angle MNP = \angle MPN = \angle MNB$. Then the circles O and O′ are orthogonal, and the circle O′ passes through the inverse (P^1) of the point P. Since all of the variable circles have PP^1 as a chord, the locus of their centers is the perpendicular bisector of PP^1.

Also solved by *F. A. Caldwell, St. Paul, Minn.*

965. *For High School Pupils. Proposed by J. F. Howard, San Antonio, Texas.*

Standing at a certain distance from a well, I observed a man drop a stone into the well. The man dropping the stone, heard it strike the bottom one second sooner than I did, and the sound of the stone striking the bottom reached my ear in one-half the time that it took the stone to fall to the bottom. Find the depth of the well.

Solved by E. de la Garza, Brownsville, Texas.

Let x be the depth of the well; t the time taken by the stone to fall the distance x; t' the time it took the sound to reach the observer, who was situated at a distance equal to the distance covered by the sound during one second, that is, equal to the speed of sound. Let v be the speed of sound (340 meters).

From the law of falling bodies and the conditions stated we get the two equations

$$x = gt^2/2, \text{ and } x + v = vt', \text{ and } t = 2t'.$$

Solving these equations we get

$$x = \frac{v[(v-4g) \pm \sqrt{v(v-8g)}\ ]}{4g}.$$

Using $g = 9.8$ meters, and the above value of v

$$x = 22.55 \text{ meters, or } 5{,}195 \text{ meters.}$$

Also solved by *Watson Dalton, Okmulgee, Okla.; Emerson M. Keeler, Miami, Florida.*

PROBLEMS FOR SOLUTION.

976. *Proposed by Tillie Dantowitz, Philadelphia, Pa.*

Determine the locus of the vertex of a triangle, given the difference of the two sides, and the radius of the inscribed circle.

977. *Proposed by I. N. Warner, Platteville, Wis.*

Solve by any method.

$$X^4 + Y^4 = 272$$
$$X + Y = 6.$$

978. *Proposed by Nathan Altshiller-Court, Norman, Okla.*

The lines joining the points of intersection of two given circles to any point on one of these circles determine in the second circle a chord subtending at any point of the second circle an angle equal to the angle of intersection of the two given circles.

Consider the special case when the given circles are orthogonal.

Consider the case when the point taken on the first circle coincides with one of the points of intersection of the two given circles.

979. *Proposed by J. F. Howard, San Antonio, Texas.*

If 20 persons agree to name a number not greater than 20, what is the chance (1) that no two persons name the same number, (2) that they all name the same number?

980. *Proposed by John Ankebrant, Gunnison, Colorado. For high School Pupils.*

Sacks of salt are placed end to end on a conveyor which is moving at a uniform rate of speed. A man walking in the same direction as the conveyor starts at the first sack and walks until just past the 25th sack. He then turns about and walks back to the first sack, which now is where the 25th sack originally was. How many sack-lengths did he walk?

A NEW CATALOG.

The Chicago Apparatus Company has issued a new four hundred and fifty page catalog that typifies the spirit of quality that pervades this progressive firm. Printed on heavy enamelled paper and with excellent illustrations, this is undoubtedly the finest scientific apparatus catalog published that contains complete listings of Physics, Chemistry, Biology (all phases), and Agriculture equipment.

From a catalog of sixty-four pages in 1908 to the present large and complete volume is an indication of the acceptance that is being accorded the Chicago Apparatus Company as a source of scientific supplies. In line with the greater size of their catalog is the increase in production to meet the demand for Milvay products. Photographs in the catalog, of various departments in their new large building show the extent to which the Chicago Apparatus Company has gone to supply the needs of their customers with increased efficiency. A two thousand per cent increase in sales in the past nineteen years testifies to the excellence of the service and products that they offer.

The catalog that they have just published is replete with new and refined items. From the excellent illustrations and descriptions of these new items it is safe to predict that many of them will be seen in the near future in the laboratories of progressive science teachers.

Teachers of Physics will be especially interested in a number of items never before listed in any scientific apparatus catalog. A line of radio testing apparatus which enables any part of the radio circuit to be tested should prove of interest at this time. The new line of Milvay bakelite case electrical meters are announced for the first time in this catalog and from the description and prices they will no doubt be extremely popular.

Buyers of scientific apparatus will do well to acquaint themselves with the contents of this catalog, not only because of the many new and improved items listed in it, but also to become familiar with the latest market prices on equipment for science laboratories.

LARGEST SOUTHERN TELESCOPE.

The largest telescope in the southern hemisphere, an instrument exceeded in size by only two others in the world, will be in operation at the new South African station of the Harvard College Observatory within the next two years, it was announced recently by Dr. Harlow Shapley, director of the observatory. The contract for this giant research instrument has just been awarded to a firm in Pittsburgh, Pa., that has made many large telescopes, including the 72-inch reflector at the Dominion Observatory, Victoria, B. C., the world's second largest.

The new Harvard telescope will be a reflector also, in which a concave mirror 60 inches in diameter replaces the convex lens of the more familiar, or refracting type. The mirror faces the star, and as it is concave, or dish-shaped, the light rays converge after being reflected from it. They are reflected to the side of the instrument by a second, flat mirror, in one type, and are brought to a focus on a photograph plate, or in an eyepiece if the telescope is being used visually.

So far, the exact site of the new station has not been decided, but it will be somewhere in the Union of South Africa, and the capital of Orange Free State, Bloemfontein, is being given serious consideration. Since 1890 the Harvard Observatory has operated a branch station at Arequipa, Peru, for the purpose of studying stars and other celestial objects that never rise above the horizons of northern countries. However, as cloudy weather handicapped the observation from Peru for a large part of each year, the high plateaus of South Africa were found to be better for continued work the year round. The instruments from the Peruvian station are now being prepared for moving by Dr. John Paraskevopoulos, who has been in charge for the last four years. These include a photographic telescope with a double lens, 24 inches in diameter, one of the largest of its kind, another with a triple lens ten inches in diameter, and three other photographic telescopes. New mountings are being provided for the first two instruments.—*Science News-Letter.*

SCIENCE QUESTIONS.

Conducted by Franklin T. Jones,
The White Motor Company, Cleveland, Ohio.
Please address all communications to Franklin T. Jones, 10109 Wilbur Ave., Cleveland, Ohio.

A QUESTION AND ITS ANSWERS.

The following question was sent in to the Editor. Two answers are attached. How would *you* answer?

490. *Question from Miss Leona McClelland, R. F. D. No. 2, Antwerp, Ohio.*

Will you please inform me why a vacuum tube is used with a transformer for amplification in the radio, and not in the telephone?

Answer—By George W. Hilterman, Cleveland, Ohio.

A transformer in the radio set is used for the purpose of amplifying your radio signal received in your detector circuit. The detector tube is a rectifier which transforms the inaudible radio frequency currents into audible signals to be received on head phones. This detector tube is not supposed to be used with the loud speaker.

Answer—By H. M. King, Experimental Research Engineer, Cleveland, Ohio.

The energy which comes to your radio is very, very small. In comparison with the energy (or current) which actuates the receiver of your telephone it is only a few millionths. The reason for this small value is that so much is lost in the transmitting.

The radio sending station is broadcasting in all directions to thousands of people and consequently very little energy gets to any particular one. When you talk to someone on the telephone all the energy is confined by the wires and is carried to your ear.

In some cases such as the transcontinental telephones, vacuum tubes and transformers are used. In simple words the use of the vacuum tube and transformer is to amplify or make greater the energy which is left when a great amount of the original energy has been lost.

If you would like to read a little more about the functioning of vacuum tubes and radio apparatus, a very non-technical booklet can be procured from the Bureau of Standards. Send to The Superintendent of Documents, Government Printing Office, Washington, D. C.

Enclose 10 cents with the request for "Elementary Principles of Radio Communication."

ANOTHER QUESTION.

What is the answer?

491. *Question by J. C. Packard, Brookline, Mass. Test Problem on Archimedes' Principle for Juniors.* A balloon filled with hydrogen gas floats in midair. A basket carrying two men and a bag of sand is attached to the gas-bag by a net-work of small cords.

Underscore by a single line one or more of the following words to indicate what, in your judgment, tends to keep the balloon up and, in a similar manner, indicate by a double line what tends to keep the balloon down.

Hydrogen surrounding air men cords gas-bag sand.

AN EXAMINATION PAPER.

492. Do teachers approve of such examinations given by some one other than the teacher? Why or why not?

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PHYSICS.

Monday, September 13, 1926—1.15 to 4.15 p. m., only.

Answer 10 questions, selecting at least two from each group. Papers entitled to less than 75 credits will not be accepted.

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Group I.

Answer at least two questions from this group.

1. Name *three* properties of musical tones. On what characteristic of sound waves does *each* of these properties depend?

2. State the laws of vibration of strings. Explain (*a*) how *one* of these laws is made use of in tuning a violin, (*b*) how it is possible to play a scale on one string of a violin.

3. Name the fixed points of a thermometer. Draw two parallel vertical lines of equal length. Using these lines as thermometers, show how the fixed points are related to each other, marking the numbers for these points in the centigrade and Fahrenheit scales. Change a reading of 60° centigrade to its corresponding Fahrenheit reading and mark the points on your diagram. Change 60° Fahrenheit to the corresponding centigrade reading and mark the points on your diagram.

4. Using labeled diagrams, show the position of the valves (open or closed) and the direction in which the piston is moving in *each* of the cycles of a four cycle gas engine. Using *one* word in each case, tell what occurs in each of the cycles. Mention *one* practical application of the four cycle gas engine.

5. Which is preferable for reading or sewing, a table lamp or an overhead lamp? State the law on which you base your answer. Would you select light or dark wall covering for a room with one small window? Explain fully the reason for your answer.

Group II.

Answer at least two questions from this group.

6. Define (*a*) a magnetic substance, (*b*) a nonmagnetic substance. Give an illustration of each. Make a diagram showing the lines of force in a magnetic field produced by two bar magnets in line with a north and a south pole placed one inch apart. Label the poles and show by means of arrows the direction of the lines of force.

7. Describe and explain the process of charging a gold leaf electroscope positively, giving at least *four* steps in the process and numbering what you consider to be each step. Name the process by which the electroscope is charged.

8. If the A battery of a radio set consists of two dry cells in parallel, each cell having an electromotive force of 1.5 volts and an internal resistance of .05 ohms, how much current will flow through the lamps if the controlling rheostat has a resistance of 20 ohms?

9. Mention *three* different effects of an electric current and give a practical illustration of each. State a rule for determining the polarity of an electromagnet. Illustrate the rule by a diagram.

10. On a 110 volt circuit find (*a*) the cost of operating for 2 hours at 8c per kilowatt hour an electric flatiron that uses 550 watts of energy, (*b*) the current flowing through the iron, (*c*) the heat produced by the iron. [$H = .24C^2\ Rt$]

Group III.

Answer at least two questions from this group.

11. Make a labeled diagram of a lift pump when the piston is moving down. What causes the water to enter the cylinder? Mention *one* practical use of an air compression pump.

12. A body starts from a state of rest and moves with uniformly accelerated motion, acquiring in 10 seconds a velocity of 3600 feet per minute. What is the acceleration per second per second? How far does the body go in 10 seconds?

13. A stiff bar firmly fastened at one end sticks out horizontally 12 feet over a cliff and will just support without breaking a weight of 150 pounds at the other end. How far out on the bar may a weight of 200 pounds be placed with safety?

14. A boy rolls a 225 pound barrel into a wagon 4 feet above the ground. He can push with a force of 50 pounds. How long a plank will he need?

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**Adopted by the Board of Control of the Ohio Teachers Reading Circle, April, 1927*

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How much work does he do? What is the ratio of the height to the length of the plane?

15. Define energy. Name *two* forms of energy and give an example of each. State the law of conservation of energy. What is meant by transformation of energy?

WORLD FEDERATION CONFERENCE.

TORONTO, AUGUST 7-12.

From present indications, there will be in the neighborhood of five thousand in attendance at the Toronto meeting of the World Federation of Education Associations, August 7-12, 1927. Adequate accommodations are being provided for all and the welfare of none will be lost sight of. The program will be varied enough and rich enough to warrant this attendance and definite, purposeful agenda will guarantee that many issues vital to the educational interests of the family of nations will be considered.

Men and women widely known for their views and accomplishments will address the Convention. Reports will be made on the several committees set up in the Herman-Jordan Plan, together with a definite program of what may be done by education to allay national jealousies and racial and religious hatreds. It is expected that a definite, sane and effective program will be evolved. While discussion groups may deal with almost all phases of education, it is the purpose of the Federation to confine itself first of all to a few essentials such as may be set up in the plan above mentioned.

The integration of the educational forces world-wide is one of the important movements of the present day. It is sponsored by the National Education Association of the United States. It seeks to curb itself against radicalism in education and to hold definitely to lines of procedure which have been tested and proved true and will apply these to the international field.

One of the direct benefits which will accrue from such a meeting is the bringing together of groups of educators from different countries who may become acquainted with each other, discuss educational problems in all parts of the world, thus broadening the viewpoint and conception of teachers everywhere. There is no attempt to standardize education in the different countries but to use the racial and national traits and characteristics, traditions and backgrounds such as they are, to weave them together with a more sympathetic understanding into a great cause worldwide. A program of education is essential to international understanding.

War is the result of misunderstanding. Misunderstanding and national hatreds are the result of ignorance, and ignorance is a direct problem of education. One need not be a delegate to enjoy the group discussions and the general programs. We believe that persons who attend the Convention will receive inspiration and information which will be beneficial in uniting the five million teachers of the world who are teaching the three hundred million children into bonds of fellowship and sympathy which will make of education a cause and a vital force in directing the trend of civilization to a higher plane.

IMPORTANT NOTICE.

Address all communications to the Canadian Committee of Arrangements, World Federation Conference, Toronto, August 7-12, to the Chairman, Canadian Committee of Arrangements, 220 Simcoe Hall, University of Toronto, Toronto, Canada.

N. B. Do not send any communications to personal addresses.

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J. C. Drummond, University of London

Hans Tropsch, Coal Research Institute, Muhlheim-Ruhr, Germany

James Kendall, F. R. S., New York University

Harry N. Holmes, Oberlin College

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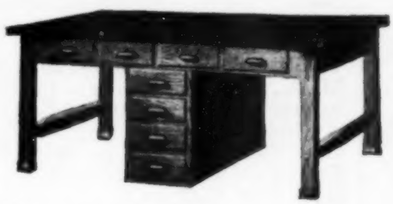

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ARTICLES IN CURRENT PERIODICALS.

American Botanist, April, Willard N. Clute & Co., Joliet, Ill., $2.00 a year, 50 cents a copy. Bladderwort and Spatter Dock by William Alphonso Murrill. The Meaning of Plant Names—XXX the Borageworts by Willard N. Clute. In Defense of the Mullein by Fannie M. Heath.

American Journal of Botany, March, Brooklyn Botanic Garden, Lancaster, Pa., $7.00 a year, 75 cents a copy. Stem and Leaf Structure of Aspen at Different Altitudes in Colorado by Paul F. Shope, University of Colorado, Boulder, Colorado. The Toxicity of Tissue Juices for Cells of the Tissue by Silvest Prat, Laboratory of Plant Physiology, Harvard University, Cambridge, Mass. Ginkgo a Flowerless Seed Plant by John H. Schaffner. Annual Versus Biennial Growth Habit and Its Inheritance in Melilotus Alba by Hugh Burnice Smith. Toxicity as Evidenced by Changes in the Protoplasmic Structure of Root Hairs of Wheat by Ruth M. Addoms, University of Wisconsin.

The American Mathematical Monthly, March, Menasha, Wis., $5.00 a year, 60 cents a copy. Frederick the Great on Mathematics and Mathematicians by Florian Cajori, University of California. Note on the Computation of Roots by J. V. Uspensky, Carleton College. On an Application of Bouguer's Theorem by James Pierpont, Yale University.

Condor, March-April, Bi-Monthly, Cooper Ornithological Club, Berkeley, Calif., $3.00 a year, 50 cents a copy. Black Swifts Nesting in Yosemite National Park by Charles W. Michael, Yosemite, Calif. Experiences with Cardinals at a Feeding Station in Oklahoma by Margaret Morse Nice, Norman, Oklahoma. Three Notable Nesting Colonies of the Cliff Swallow in California by Tracy I. Storer, Davis, Calif.

Education, March, The Palmer Co., Boston, $4.00 a year, 40 cents a copy. The Rise of Universities During the Middle Ages by Prof. K. A. Sarafian, M. A., La Verne College, La Verne, Calif. Specific Objectives Versus Adaptability as the Aim of Education by R. Ray Scott, M. A., Professor of Education, West Virginia Wesleyan College, Buckhannon, W. Va. Why These Projects? by Nellie W. Donley, Morgantown, West Virginia. The Problem of the Model School by Benjamin Deutsch, 1319 Clay Ave., New York City.

Journal of Chemical Education, March, Rochester, N. Y., $2.00 a year, 35 cents a copy. The Utilization of Geothermal Power in Tuscany by Prince Ginori Conti, 58A, Via Scala, Florence, Italy. History of the Chlorine Industry by Robert T. Baldwin, Secretary, The Chlorine Institute, Inc., New York City. The Vitamins. V by H. C. Sherman, Columbia University, New York City. The Reality of the Atom by Wheeler P. Davy, Research Staff, General Electric Co., Schenectady, N. Y. The Contribution of Aniline to Economic and Social Progress During the Past One Hundred Years by M. L. Crossley, Calco Chemical Co., Bound Brook, N. J.

Journal of Geography, April, A. J. Nystrom and Co., 2249 Calumet Ave., Chicago, $2.50 a year, 35 cents a copy. Nicaragua: Revolution and Intervention by Robert S. Platt, University of Chicago. Notes on the Geography of Trinidad by Preston E. James, University of Michigan. Unit Topics Suitable for Junior High School Geography by Maude Cottingham Martin, Junior High School, Cleveland Heights, Ohio.

Mathematics Teacher, March, National Council of Teachers of Mathematics, Yonkers, N. Y., $2.00 a year, 40 cents a copy. Some of Euclid's Algebra by George W. Evans. A Number of Things for Beginners in Geometry by Vesta A. Richmond, Newton High School, Newton, Mass. Objectives in Teaching Intermediate Algebra by Professor W. D. Reeve, Teachers College, Columbia University.

National Geographic Magazine, April, Washington, D. C., $3.50 a year, 50 cents a copy. The Races of Domestic Fowl by M. A. Jull, Ph.D., Poultry Husbandman, Bureau of Animal Industry, U. S. Department of Agriculture. America's Debt to the Hen by Harry R. Lewis. Farmers Since the Days of Noah by Adam Warwick.

Popular Astronomy, April, Northfield, Minnesota, $4.00 a year, 45 cents a copy. Report on Mars, No. 39 by William H. Pickering. The Fireballs

of December 9, 1926 by A. L. Bennett. Astronomical and Meteorological Conditions of the Eclipse of the Sun May 9, 1929 in the Philippines by Miguel Selga.

Science, March 18, Grand Central Terminal, New York City, $6.00 a year, 15 cents a copy. Some Recent Speculations on the Nature of Light by Professor B. Wilson, School of Public Health, Harvard University. The Conception of a Species by Dr. C. C. Hurst, Trinity College, Cambridge, Mass.

Scientific American, April, New York, $4.00 a year, 35 cents a copy. Missing Links of the Gobi Desert by Dr. William K. Gregory, Professor of Vertebrate Paleontology, Columbia University. The Next Great Comet is About Due by Henry Norris Russel, Ph.D., Professor of Astronomy at Princeton University. Fishes That Can Shock You by Professor David Starr Jordan, Chancellor Emeritus, Leland Stanford, Jr. University. Transporting a River Over Mountains by Edgar Lloyd Hampton.

Scientific Monthly, April, The Science Press, New York, $5.00 a year, 50 cents a copy. Contributions That Have Been Made by Pure Science to the Advancement of Engineering and Industry; Introduction by Dr. C. R. Richards, Lehigh University. Astronomy by Dr. Frank Schlesinger, Yale University Observatory. Biological Science by Professor Henry B. Ward, University of Illinois. Chemistry by Dr. Charles H. Herty, Adviser, The Chemical Foundation, Inc. Economics by Professor Joseph H. Willits, University of Pennsylvania. Geology by Professor Heinrich Ries, Cornell University. Mathematics by Professor Gilbert Ames Bliss, University of Chicago. Public Health by Professor Randle C. Rosenberger, Jefferson Medical College, Philadelphia. Psychology by Dr. J. McKeen Cattell, Chairman of the Directors of the Psychological Corporation. The Mongolian Age of Mammals by Professor William K. Gregory, American Museum of Natural History. The Life History of the Fish Astroscopus (The "Stargazer") by Professor Ulric Dahlgren, Princeton University.

School Review, April, The University of Chicago Press, $2.50 a year, 30 cents a copy. The Problem of Student Honor in Colleges and Universities by R. L. Lyman, University of Chicago. Improving the Objective-Test Question by J. T. Giles, State High School Supervisor, Madison, Wisconsin. A Study of Achieving and Non-Achieving High-School Pupils by Austin H. Turney, University of Minnesota.

BOOKS RECEIVED.

Problems in Logic by Charles Henry Patterson, Ph. D., of the Department of Philosophy in the University of Nebraska. Cloth. Pages xii+331. 18.5x12.5 cm. 1926. The Macmillan Company, New York.

New Civic Biology by George William Hunter, Ph. D., Professor of Biology, Knox College, Galesburg, Illinois. Cloth. Pages xii+448. 20x13 cm. 1926. American Book Company. Price $1.68.

The New Everyday Arithmetic, First Book by Franklin S. Hoyt, formerly Assistant Superintendent of Schools, Indianapolis, Indiana and Harriet E. Peet, Research Worker in Education, Cambridge, Massachusetts. Cloth. Pages xiv+338. 18.5x12.5 cm. 1926. Houghton Mifflin Company. Price 76 cents.

The New Everyday Arithmetic, Second Book by Franklin S. Hoyt, formerly Assistant Superintendent of Schools, Indianapolis, Indiana and Harriet E. Peet, Research Worker in Education, Cambridge, Massachusetts. Cloth. Pages viii+376. 18.5x12.5 cm. 1927. Houghton Mifflin Company. Price 80 cents.

The New Everyday Arithmetic, Third Book by Franklin S. Hoyt, formerly Assistant Superintendent of Schools, Indianapolis, Indiana and Harriet E. Peet, Research Worker in Education, Cambridge, Massachusetts. Cloth. Pages xii+420. 18.5x12.5 cm. 1927. Houghton Mifflin Company. Price 92 cents.

Plane Geometry by D. Meade Bernard, B. S., LL.B., Head of the Department of Mathematics, Duval High School, Jacksonville, Florida

with the Editorial Cooperation of Alfred Wilson Philips, A. M., Head of the Department of Mathematics, Kansas State Teachers College of Emporia. Cloth. Pages xv+334. 19x12.5 cm. 1927. Johnson Publishing Company, Richmond, Virginia. Price $1.24.

Junior High School Mathematics, Eighth School Year by Harry C. Barber, Head of the Mathematics Department in the Charlestown High School, Boston, and Supervisor of Mathematics in the Public Schools of Newton, Massachusetts, assisted by Helen M. Connelly, Rice and Quincy Schools, Boston and Elsie V. Karlson, Frank V. Thompson School, Boston. Cloth. Pages xiv+267. 18.5x12 cm. 1927. Houghton Mifflin Company. Price $1.00.

Differential Geometry of Three Dimensions by C. E. Weatherburn, M. A., D. Sc., Professor of Mathematics at Canterbury College, University of New Zealand. Cloth. Pages xii+268. 21.5x13.5 cm. 1927. The Macmillan Co.

The Polarimeter—a Lecture on the Theory and Practice of Polarimetry by Vivian T. Saunders, M. A., Fellow of the Physical Society of London. Cloth. Pages 29. 24.5x15 cm. Adam Hilger, Ltd., 24 Rochester Place, London, N. W. 1 England. Price 40 cents.

Elementary Solid Geometry by V. B. Naik, M. A., Professor of Mathematics, Fergusson College, Poona, India and S. B. Bondale, M. A., Professor of Mathematics, Willingdon College, Dt. Satara. Cloth. Pages v+220. 17.5x12 cm. 1926. Vishwanath Balvant Naik and Shridhar Bhikaji Bondale at Poona, India.

Two Lectures on the Development and Present Position of Chemical Analysis by Emission Spectra by F. Twyman, F. R. S., F. Inst. P. Cloth. Pages 43. 24x15.5 cm. Published by Adam Hilger, Ltd., 24 Rochester Place, London, N. W., England. Price 66 cents.

Digest of Elementary Chemistry by Martin Mendel, M. A., Thomas Jefferson High School, Brooklyn, New York. Paper. v+234. 18.5x11.5 cm. 1927. Globe Book Company, New York.

Elements of Chemistry by Harry N. Holmes, Professor of Chemistry, Oberlin College and Louis W. Mattern, Head Teacher of Chemistry, McKinley Technical High School, Washington, D. C. Cloth. Pages x+519. 19.5x13 cm. 1927. The Macmillan Company.

Modern Plane Geometry by John R. Clark, The Lincoln School Teachers College, Columbia University and Arthur S. Otis, author of Statistical Method in Educational Measurement and Otis-Administering Tests of Mental Ability. Cloth. Pages x+310. 18.5x13 cm. World Book Company. Price $1.36.

The Unity of Life—a Book of Nature Study for Parents and Teachers by H. R. Royston, M. A., with Sixteen Plates and Twenty-three Diagrams in the Text. Cloth. Pages 280. 19.5x12.5 cm. 1926. World Book Company. Price $2.00.

The Buckingham-Osburn Searchlight Arithmetics, Book One by B. R. Buckingham, Director of the Bureau of Educational Research, Ohio State University and W. J. Osburn, Director of Educational Measurements, State Department of Public Instruction, Madison, Wisconsin. Cloth. Pages xiii+358. 19x13 cm. 1927. Ginn and Company. Price 76 cents.

BOOK REVIEWS.

The Buckingham-Osburn Searchlight Arithmetics. Introductory Books by B. R. Buckingham, Director of the Bureau of Educational Research, Ohio State University, and W. J. Osburn, Director of Educational Measurements, State Department of Public Instruction, Madison, Wisconsin. Pp. XV+381. 15x19.5 cm. Boston: Ginn & Co. $1.00. 1927.

This is a teachers' book designed for teachers of the first and second years of school. It is preliminary to a series of pupils'books for the first six years and the junior high school. It is intended to furnish material and the method for the pre-third-grade period. Some of the features of the method are the following:

1. To reduce error and to discourage guessing combinations are posted

for reference. To prevent the pupil from forming the habit of counting, each combination is presented in the first instance by a whole-to-part rather than by a part-to-whole method.

2. The addition and subtraction facts are taught together.

3. Much attention is given to drill on the combinations after they have been learned. The extent of the drill on any combination is determined by its difficulty.

4. Numerous and interesting problems are supplied for practice in using the combinations in concrete situations.

A teacher of mathematics who has not been directly interested in primary number work will be amazed at the amount of investigation that has been made in this field. He will also learn that the primary teacher has a "man's job" in mastering the material and the technique of its presentation. J. M. Kinney.

Instructional Tests in Algebra, With Goals for Pupils of Varying Abilities. By Raleigh Schorling, John R. Clark, and Selma A. Lindell. pp. VIII+72. 13.5x19 cm. Heavy paper. $.28. Yonkers-on-Hudson, New York: World Book Company.

Dr. Schorling, of the University of Michigan, and Dr. Clark, of Columbia University, have spent many years in investigations pertaining to the psychology of learning in general and in particular to secondary mathematics. They are authorities in this special field. One may feel assured that this set of tests designed by them after years of experimentation is a superior piece of work.

To have a pupil become interested in his improvement is of prime importance. The authors have attempted to bring this about by applying certain definite principles from the psychology of drill. Chief among these principles are the following:

1. A drill exercise must be specific.

2. A drill exercise should be standardized so that the pupil may have at least a rough notion of his degree of mastery.

3. Drill must provide a scoring technique so that a pupil may watch his growth day by day.

4. Drill to be effective must be individual.

5. In general, there should be much practice on a few skills, rather than a little practice on each of many things.

6. Drill material should be so constructed as to make possible the diagnosis of individual disabilities, and it should provide each pupil the opportunity to concentrate upon those processes which present peculiar difficulty to him.

These tests are to be used as a supplement to an algebra text. A particular test is to be given after the teacher has carefully developed the theory involved and has given the pupils an opportunity to practice on the exercises found in the text.

The technique is such as to make the administration of these tests very simple. The two important factors of administration are the *timing* of the tests and the *recording* of the results. Standards or goals on each test are suggested for each of three levels of ability. The pupils may themselves check each test as soon as it is passed. J. M. Kinney.

Physics for Colleges by H. Horton Sheldon, Ph. D., Associate Professor and Chairman of the Department of Physics, Washington Square College, New York University, C. V. Kent, Ph. D., Associate Professor of Physics, University of Kansas, Carl W. Miller, Ph. D., Assistant Professor of Physics, Brown University, Robert F. Paton, Ph. D., Associate Professor of Physics, University of Illinois. Cloth. Pages vi+655. 21.5x13.5 cm. 1926. D. Van Nostrand Company, 8 Warren Street, New York.

During the past five or six years a number of text books of general physics have appeared each claiming to have incorporated the recent developments in the subject. In general these statements have been well founded but the new material has been presented most frequently in a

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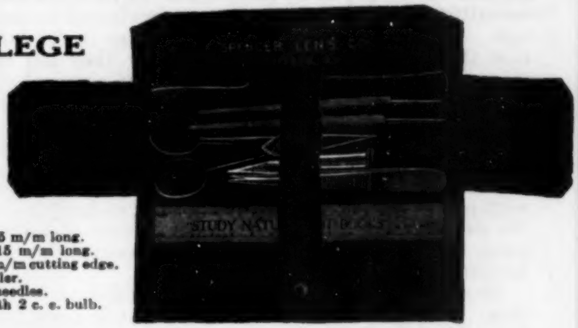

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chapter or two set off by itself while the phenomena, descriptions of which constituted much of the text, were explained in the language of a decade ago. Here is a text which tells the story in the language of today. The new theories are introduced wherever they aid in explaining. Recent researches are discussed along with the classical ones to which they are related. The authors have been highly successful in including the new without eliminating the old essentials.

Each of the four authors has been responsible for a particular division of the book thus being able to concentrate on a limited amount of subject matter of especial interest to himself, yet all four worked in accordance with one plan. Related subjects such as heat and molecular physics, i.e. the subjects built upon the kinetic theory of matter, make up one division; light and sound naturally connected by their relation to wave motion form another, etc.

Mechanically the book is well arranged and well adapted for instruction. The chapters are short and include good questions and problems. In order to stimulate thought and prevent mere memorizing, italics and bold faced type have been avoided. College classes will be delighted with this text and it will be a valuable reference for all high schools.

G. W. W.

How to Write a Thesis, by Ward G. Reeder, Assistant Professor of School Administration, Ohio State University. Cloth. Pages 136. 16.5x10.5 cm. 1925. Public School Publishing Conpany, Bloomington, Illinois. Price 90 cents.

The biggest problem before the candidate for a graduate degree is the preparation of the thesis. Either he has no topic of major interest and does not know how to find one, or he has one and does not know how to investigate it and make his report. Professor Reeder's little book gives valuable help in both of these perplexing situations. It gives the candidate the proper cue and relieves the instructor of repetition to each candidate. If the suggestions are followed time will be saved by preventing much of the rewriting that is so frequently necessary in order to make the product a credit to its author and his university. Candidates for degrees and professors in charge of this work will find the book quite worthy of their attention.

The many hints given for writing in general, and for preparation of articles for publication make the book valuable to many others not primarily interested in writing a thesis. G. W. W.

Properties of Inorganic Substances, by Wilhelm Segerblom, A. B., Instructor in Chemistry at the Phillips Exeter Academy. Cloth. Pages 226. 23x15cm. 1927. The Chemical Catalog Co., Inc., 19 East 24th Street, New York.

This book is a revision of the author's previous work, "Tables of Properties of Over Fifteen Hundred Common Inorganic Substances." It is designed as a reference book for students in qualitative analysis, and enables corroboration of results given by tests in salt analysis. This revision includes the most recent data and brings the work up to date practically complete and reliable for the principal properties of substances studied in the ordinary courses in qualitative analysis.

The six groups of metals according to Fresenius, together with their oxides, hydroxides and more common salts are tabulated in columns, thus making comparison and contrast easy and convenient. Each group is introduced by a descriptive paragraph giving the principal properties of the group. In addition to these six groups the properties of the acids and of the non-metals and the rare metals are conveniently tabulated. The tables give color, luster, crystalline form, deliquescence, efflorescence, stability in air, action on test paper, melting point, behavior when heated, solubility in water, alcohol and acid, and other properties characteristic of the substance under consideration. The formulas, chemical names and their common names are also given. The student in qualitative analysis should find this book an invaluable source of reference. L. C. W.

The Embryology of the Pig, by Bradley M. Patten, Associate Professor of Histology and Embryology, School of Medicine, Western Reserve University. 1st Edition. Pages IX+323. 15x22.5 cm. Cloth. 1927. $3.50. P. Blakiston & Co., Philadelphia.

The pig has for years been a favorite subject for embryologie study because of its availability, but it was left for Dr. Patten to be the first to present in concise form a readable text on mammalian embryology based on the pig. This book, the complete in detail, is written in such interesting style, and printed in large type on good paper, that it at once appeals to the student. The chapters are well outlined, and the several topics are clearly captioned. Dr. Patten first established a radical departure in the nature of medical texts when he wrote the Early Embryology of the Chick, which is a very brief, but complete treatise on chick embryology. In it the author succeeded in bringing out principles without so many unnecessary details. The present work, the Embryology of the pig is written as a supplement to the Chick embryology, and with the latter should furnish ample text for any beginning course in Embryology. We are using this combination of books in our embryology class this semester, and find them very satisfactory. Walter Lawrence.

Hygiene, A Textbook for College Students by Dr. Florence Lyndon Meredith, Smith College, Northampton, Mass. Cloth. Pages VII+719. 21x13.5 cm. 1926. P. Blakinston's Son & Co. Price $3.50.

Among the many new books devoted to the cause of promoting health few will measure up to the standard of perfection set by this one. It is written as a textbook for college students and is admirably adapted for this use but will be found interesting and valuable to anyone who has sufficient educational background.

The author recognizes that good health is in part due to more intelligent understanding of the structure and use of the organs of the body, than has been acquired in the high school course. To supply this deficiency is the aim of the first part of the book. The purpose of the introductory chapters is to bring about the proper attitudes toward health. A brief study of anatomy and physiology make up the second section. The third part discusses such pathological conditions as inflammation, infection, poisons, etc. These three sections are preliminary to, and give the necessary foundation for the discussion of personal hygiene in part four, which makes up somewhat more than half the volume.

The book is profusely illustrated with well chosen diagrams, graphs and pictures. G. W. W.